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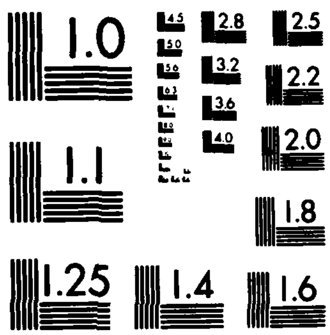

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METHODOLOGY INVESTIGATION

FINAL REPORT

REAL-TIME MESSAGE PROCESS SIMULATION CAPABILITY

BY

Richard G. Jacques

May 1984

JAN 7 1985

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US ARMY ELECTRONIC PROVING GROUND

FORT HUACHUCA, ARIZONA

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The Real-Time Message Process Simulation Capability methodology investigation was initiated to develop a method for simulating, in real-time, the responses of controlled resources in testing C3I systems. The methodology investigation reviewed the design of the Interim Test Item Stimulator, a digital message test driver. Real-time process requirements were described for both MCS and TACFIRE to provide input to the real-time requirements of the Test Item Stimulator.

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FOREWORD

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1.0 SUMMARY

1.1 Background

a. The Department of Defense (DOD) has developed and is continuing to develop a number of automated command, control, communication, and intelligence (C^3I) systems. Although each of these automated systems has a different function and a different set of requirements, the automated systems all use digital message exchange to communicate. Testing to verify that these automated systems meet their operational requirements is largely an exercise of each system's software implementation as measured by the output message stream.

b. In the past, the verification and validation of software have been accomplished by a highly individualized type of testing usually done by the software developers. Individual modules of software have been tested. However, no comprehensive test methodology has been available to verify the functionality of the software as a whole. This has resulted in unreliable products. Because the U.S. Army of the 1990's will depend upon the systems developed now, an orderly, rigorous testing methodology has been developed to augment software testing.

c. The Test Item Stimulator (TIS) is one type of tool used for testing. The Interim Test Item Stimulator (ITIS) was a test driver which was developed by the U.S. Army Electronic Proving Ground (USAEPG) for development testing (DT) of the Maneuver Control System (MCS). The ITIS has evolved into the TIS to meet additional test requirements. Test conduct using the TIS is separated functionally into three phases: pre-test scenario preparation, real-time item stimulation, and post-test data reduction and analysis.

d. The first phase is the pre-test, or the generation of test cases that will sufficiently test the system. To insure that the critical and probable paths will be sufficiently exercised during the real-time test, the test director must draw upon personal experience and understanding of the system requirements to produce appropriate scenarios and test message scripts.

e. The second phase is the real-time test. This is the conduct of the test as determined by the test director in the pre-test phase. The TIS stimulates the system under test (SUT) by transmission of prescripted messages. One function of DT is to determine how well the SUT meets its performance specifications. Because of the time criticality of the system control parameters, this type of action can occur only in real time. The results of the real-time test are recorded for use in the third phase, the post-test analysis.

f. An in-depth study of the test results is conducted during the post-test analysis phase. This is the phase wherein the SUT performance is measured against the requirements. The results of this analysis will become the substance of a test report for those tests dealing with software functionality on a system level.

1.2 Objective

The Real-Time Message Process Simulation Capability investigation was initiated to develop a method for simulating, in real-time, the responses of controlled resources in testing message-driven systems which have control functions. (See appendix A.)

1.3 Summary of Procedure

a. The objective of this investigation was accomplished through three steps.

(1) Examine representative Army C^3I systems which have real-time control functions which cannot be tested using precomposed message streams. This requires a review of the ITIS capability and an exhaustive look at selected Army C^3I system requirements.

(2) Document those specific real-time processes that need to be simulated, including the inputs and outputs required. Because the implementation of all processes is not feasible, all processes identified will be documented and the priority of implementing each process will be recommended.

(3) Provide input to the requirements of the TIS that will incorporate necessary real-time processes. The TIS is a test driver which is evolving from the ITIS to meet the testing requirements of the latest C^3I systems such as the Joint Tactical Information Distribution System (JTIDS), and the Position Location Reporting System/JTIDS Hybrid (PJH).

b. The scope of this investigation was limited to the already fielded Army executive systems, the MCS and Tactical Fire Control System (TACFIRE) of the Fire Support. Examination of the Missle Minder (TSQ-73) was performed as part of the TIS development.

1.4 Summary of Results

a. The ITIS Basic Real-Time System (BRTS) consisted of a design based upon prescripted messages from an input scenario. Some real-time processes were supported under the system because they were essential to the most basic forms of message exchange.

b. Examination of documentation for the MCS and TACFIRE systems showed that each of these systems contains processes which could be defined as real-time processes. To evaluate these tactical systems and define appropriate real-time processing for TIS; three groups of real-time processes were defined:

(1) Required Processing: Real-time processes in a SUT which are essential to message exchange and which must be included in the minimum definitions of the System-Specific Applique (SSA) component of a TIS.

(2) Desirable Processing: Real-time processing in a SUT which represents events that occur in unpredictable sequences or which may occur in response to unpredictable outside events and which should therefore be included in an SSA to test functions of the SUT fully.

(3) Scriptable Processing: Processing which occurs in real-time in a SUT which is predictable in sequence and content and which may be supported by messages which can be scripted during the pre-test phase.

c. Real-time processes identified in both MCS and TACFIRE can be placed into each of these categories. Figure 1 shows a comparison of the current and enhanced MCS SSA real-time processing with all processes categorized as described above. Figure 2 categorizes TACFIRE real-time processes which have been identified during this investigation.

d. The International Standards Organization (ISO) reference model shown in figure 3 provides a basis for comparison between diverse communications networks. Although some tactical systems have not been designed with precisely defined functional layers, as suggested by the model, a rough correlation may be drawn. Figure 4 shows this mapping of functional processes from MCS and TACFIRE to layers in the ISO model.

1.5 Analysis

Real-time processes associated with C^3I systems are amenable to categorization by reference to the ISO model. Processes may be further described as required, desirable, or scriptable. Processes from layers 4 through 7 of the ISO model are generally supportable by prescripting messages; however, many of these can be supported more efficiently by real-time processing.

1.6 Conclusions

a. The ITIS MCS capability provided stimulation with prescripted scenarios. Enhancements to the real-time capability to provide verification of future MCS capabilities was identified.

b. The requirements for real-time process simulation for both MCS and TACFIRE have been defined and are amenable to implementation in the SSA of TIS.

1.7 Recommendations

a. The present ITIS capability requires that all test messages be composed and validated prior to the start of a real-time test. The TIS design should permit the stimulus messages to reflect information changes that a SUT would expect in response to its outputs. The situation that needs to be simulated is shown in figure 5.

b. To support these real-time requirements, the TIS SSAs should include the ability to expand and implement the processes identified as required or desirable in section 1.4 for both MCS and TACFIRE.

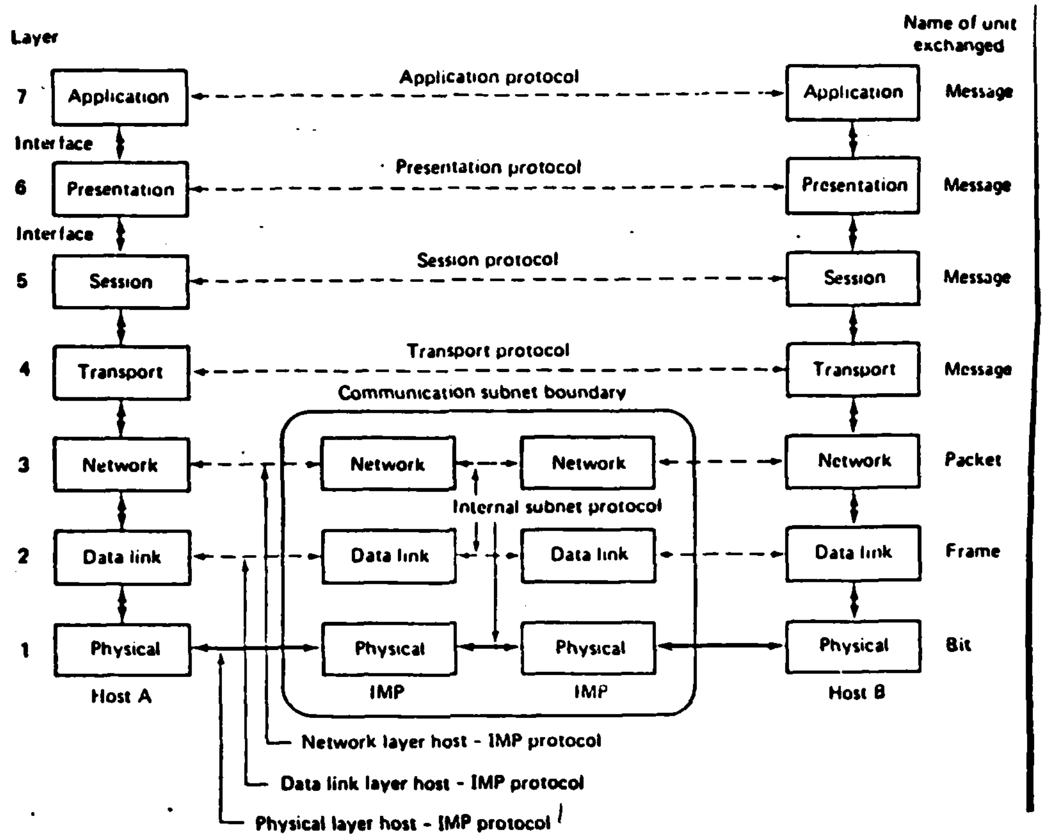
PROCESS CATEGORY	CURRENT MCS SSA CAPABILITIES	ENHANCED MCS SSA CAPABILITIES
REQUIRED	ACKNOWLEDGEMENT/RETRY ERROR DETECTION & CORRECTION (EDC) TIME DISPERSAL CODING (TDC)	ACKNOWLEDGEMENT/RETRY EDC TDC
DESIRABLE		AUTODIAL* AUTOMATIC RELAY END-TO-END ACCOUNTABILITY REMOTE DBMS REQUESTS
SCRIPTABLE	ABRIDGING	ABRIDGING**

* Requires additional hardware
** Could be supported by pre-scripting

Figure 1. MCS Real-Time Processes

PROCESS CATEGORY	TACFIRE REAL-TIME CAPABILITIES
REQUIRED	ACKNOWLEDGE/NEGATIVE ACKNOWLEDGE/RETRY EDC TDC SUBSCRIBER TABLE MAINTENANCE SERIALIZATION and VALIDATION
DESIRABLE	REMOTE LOOP TEST MESSAGE OF INTEREST ROUTING SYS;FORM RESPONSE
SCRIPTABLE	MESSAGE COMPACTION TACTICAL EVENT SIMULATION

Figure 2. TACFIRE Real-Time Processes

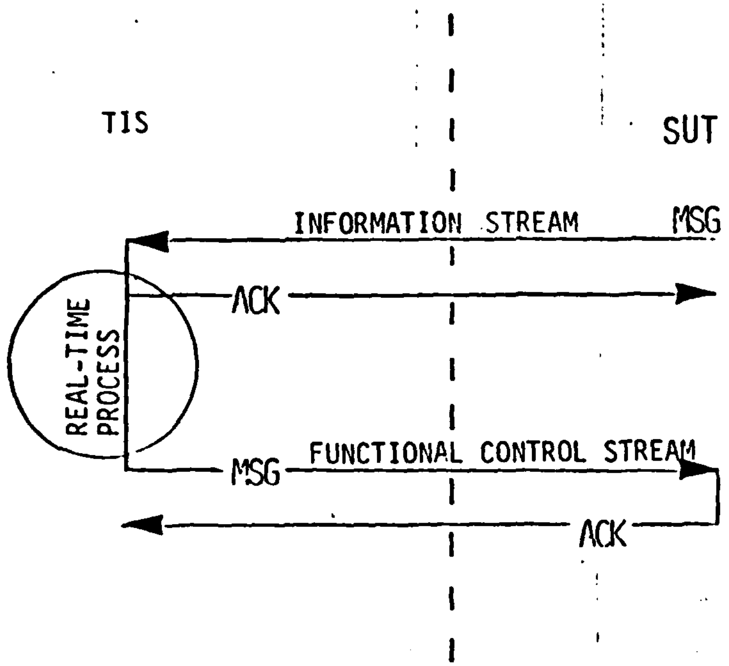


LAYER	TITLE	DESCRIPTION
1	Physical Layer	Physical connections necessary to transmit data on a bit I/O level
2	Data Link Layer	Transforms raw bits into error-free line to network layer
3	Network Layer	Groups data into packets, routes packets to destination, performs error accounting
4	Transport Layer	Accepts data from session layer, forwards to network layer, assures end-to-end accountability
5	Session Layer	User interface to network, handles connection establishment
6	Presentation Layer	Library of common application functions shared among users
7	Application Layer	Unique messages handling specific to application

Figure 3. ISO OSI Seven-Layered Model

MCS	ISO MODEL	TACFIRE
Message Format Definition	Layer 7 Application Layer	Tactical Events Simulation Message Format Definition
Abridging of Messages	Layer 6 Presentation Layer	SYS;FORM Format Skeleton Transmission Message Compaction
Remote Requests (filing, deletion, retrieval)	Layer 5 Session Layer	Serialization, Validation
End-to-End Accountability	Layer 4 Transport Layer	Message of Interest Routing Remote Loop Test
Routing/Relay Autodial	Layer 3 Network Layer	Subscriber Table
EDC/TDC/Double Blocking ACK/AUTORETRY	Layer 2 Data Link Layer	EDC/TDC ACK/NAK/AUTORETRY
FSK 4-Wire 600, 1200 Baud Conditioned Diphase 8K, 16K, 32K Baud	Layer 1 Physical Layer	FSK 4-Wire 600, 1200 Baud 55-Wire Parallel Interface

Figure 4. MCS and TACFIRE Processes Mapped to ISO Model



- SUT TRANSMITS MESSAGE
- TIS TRANSMITS ACK
- TIS PERFORMS REAL-TIME PROCESSING
- TIS INSERTS MESSAGE INTO SERIAL MESSAGE STREAM
- TIS TRANSMITS MESSAGE GENERATED BY PROCESS
- SUT TRANSMITS ACK

Figure 5. Real-Time Message Traffic

2.0 DETAILS OF INVESTIGATION

2.1 Identification of Systems

a. This methodology investigation had three main tasks. The initial task was to examine Army C^3I systems which have real-time control functions that cannot be tested using precomposed test message streams. The second task was to identify the specific processes and the required inputs and outputs for each system previously identified. The final task was to determine feasible additions to the TIS design requirements to accommodate an adequate real-time process simulation capability as those requirements and their documentation are developed.

b. The initial effort associated with this investigation was to identify Army systems for further study. The scope was limited to those systems depicted in the representation of the Army Battlefield Automated Systems (BAS) concept in figure 6. The investigation identified TACFIRE and MCS for detailed study. Both of these systems are executive systems under the BAS concept and communicate via character-oriented digital message exchange.

2.1.1 Bit-Oriented Versus Character-Oriented Messages

a. The TSQ-73 and HAWK missile systems were examined briefly to obtain a fuller understanding of the structure and philosophy of Army systems using bit-oriented messages for communications. This examination led to the conclusion that major functional differences exist between the bit-oriented and character-oriented types of message exchange.

b. The differences between the two types of message exchange are not inherent in the definition of field size in terms of bits or characters. The differences spring from the diverse purposes of the information transfered. MCS and TACFIRE messages are character-oriented. Processers being controlled by MCS and TACFIRE rely largely on operator intervention for real-time generation of messages. TSQ-73 and HAWK messages are bit-oriented. Message generation is controlled by a complex combination of outside events, operator intervention, and response to incoming message information. Processes being controlled and described by the message exchange between TSQ-73 and HAWK are time critical, and real-time computer-generated messages are essential for information exchange to be maintained.

2.1.2 Use of the ISO Protocol Reference Model

a. It is apparent that support of such widely diverse systems with a single TIS requires a well-coordinated design philosophy. It is necessary, therefore, to establish a common base for comparison of tactical communication protocols. Figure 3 illustrates the ISO reference model's layered concept of a communications protocol. The layers identified in figure 3 will be used throughout this report to describe tactical communication protocols.

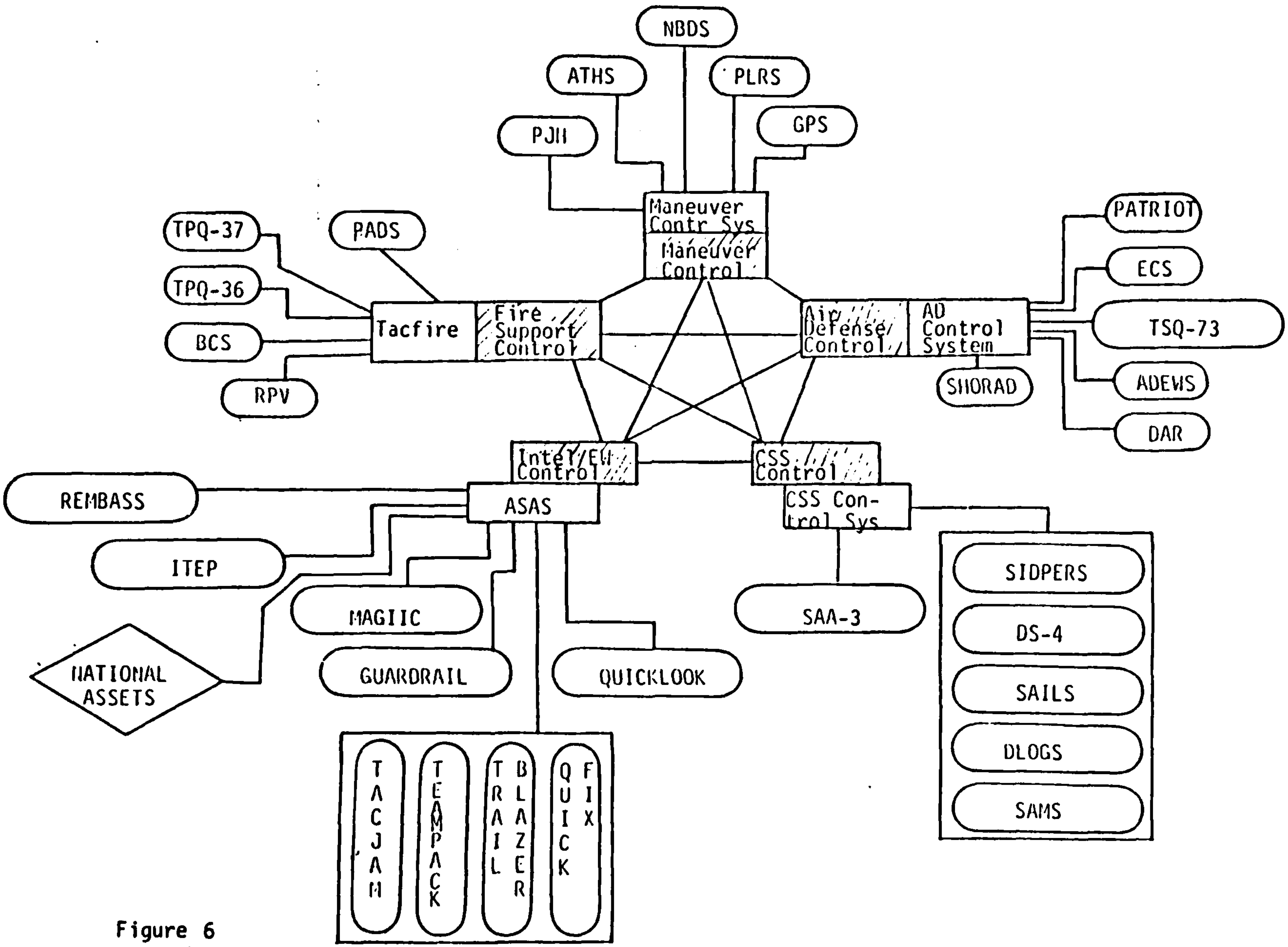


Figure 6
Army BAS Concept

b. Communication with each system requires some rudimentary communication protocol interface. In the TIS, this type of protocol handling is performed in the SSA. The SSA is the part of the TIS real-time software that performs highly specialized functions requiring re-implementation from SUT-to-SUT.

c. Layers 1, 2, and 3 of the ISO model are necessary for any message exchange to occur. These layers are mandatory for minimal SSA implementation. Layer 4 is a bridge between the essential lower three layers and the system-tailored upper three layers. Layer 4 assures end-to-end message transfer and provides logical (named) rather than physical (hard-wired) addressing of nodes. It is highly desirable to implement the layer 4 function in an SSA. This allows logical node addressing on the message-generation level. Processes representing layers 5, 6, and 7 are not essential to message exchange. Omission of processes representing layers 5 to 7 may cause error conditions or illogical event sequences. Those processes from layers 5 to 7 which must be simulated to meet testing requirements will be identified. Simulation of the sequences of events in layers 5 to 7 in a tactical protocol may be accomplished by careful scripting. This report will identify those items which can most effectively be supported by generation of messages during real time.

2.2 TACFIRE

2.2.1 TACFIRE Message Types

TACFIRE uses four basic types of messages. These are application, control, test, and system messages. These messages share the same communication line format and are transmitted using the same rules. The types differ primarily in content. They are categorized as required, desirable, and scriptable as shown in figure 2.

2.2.2 Real-Time Processes Required for SSA

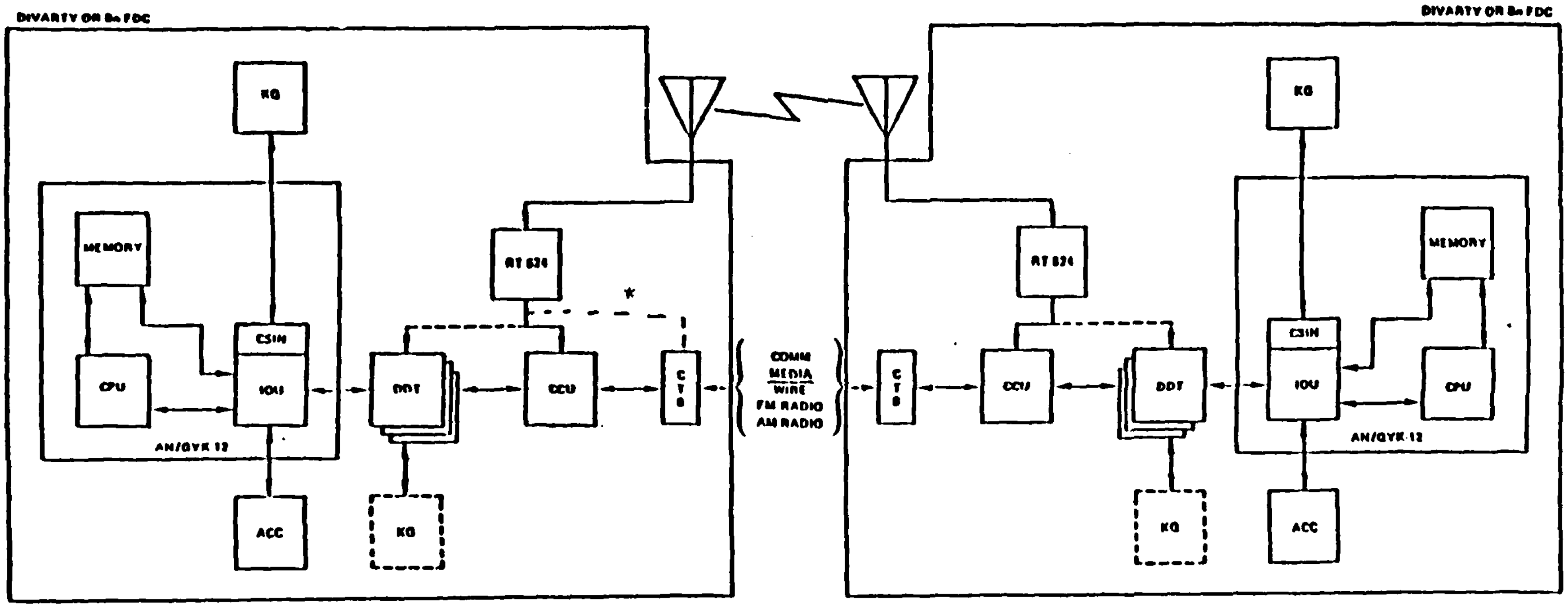
Implementation of a TACFIRE SSA that includes processes corresponding to the ISO model for layers 1 to 3 (and serialization) would allow basic message exchange. This implementation must include the five functional areas listed in table I.

TABLE I. MINIMUM TACFIRE SSA REQUIREMENTS

Physical Interface (layer 1)
Generation and Decoding of EDC/TDC (layer 2)
Generation and Response to ACK/NAK/No Response (layer 2)
Maintenance of a TACFIRE-like Subscriber Table (layer 3)
Serialization and Validation (layer 5)

2.2.2.1 Layer 1, Physical Interface

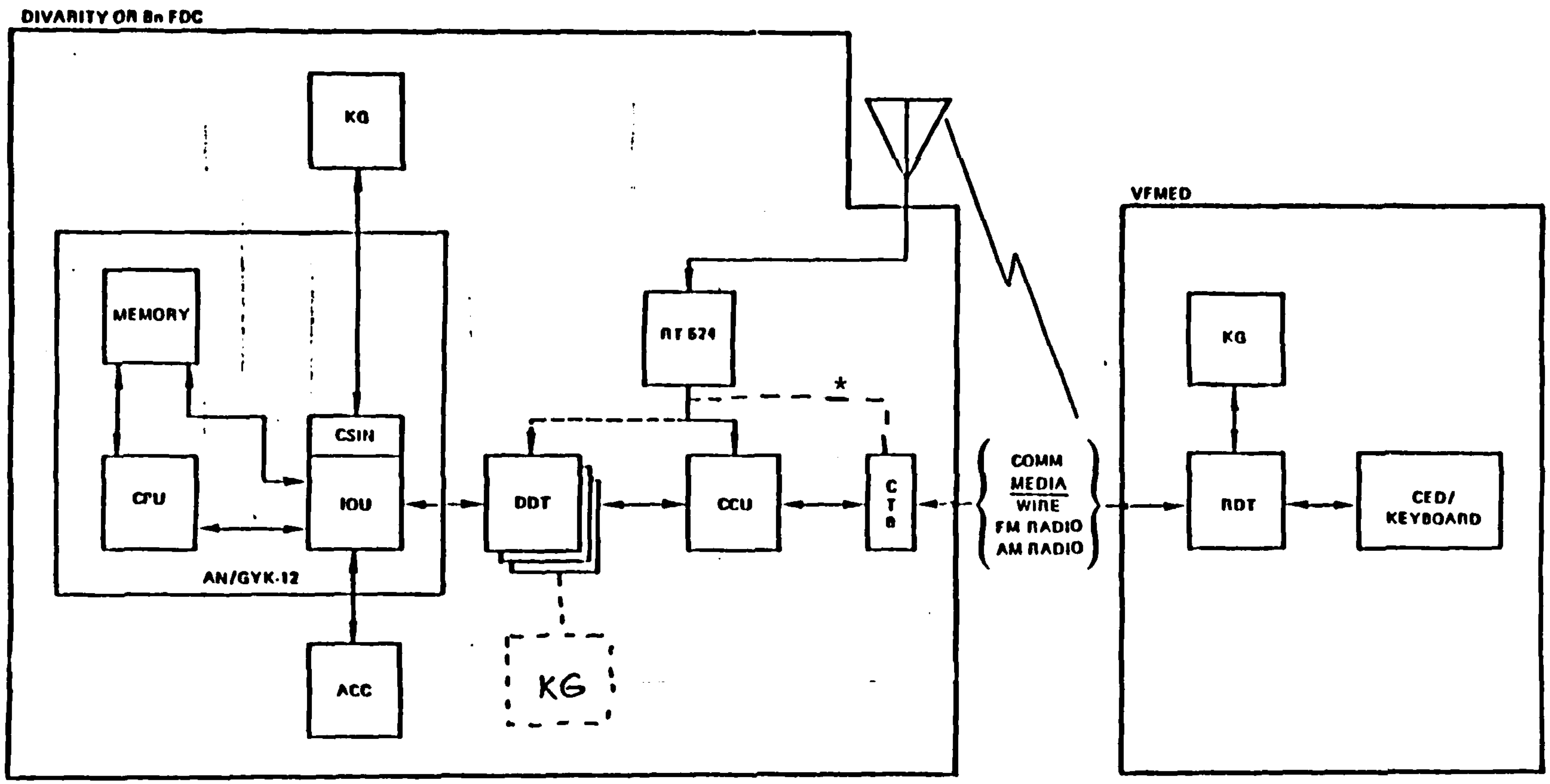
a. TACFIRE TF-A, TF-B, and TF-C interfaces support different configurations of TACFIRE equipment. As illustrated in figures 7, 8, and 9, these



NOTE: SOLID LINES INDICATE NORMAL EQUIPMENT CONFIGURATION FOR STORE AND FORWARD KG OPERATION. DASHED LINES INDICATE OPTIONAL CONFIGURATIONS, WHERE THE KG IS USED ON LINE, DATA COMMUNICATIONS WITH REMOTE DEVICES ARE NOT AVAILABLE.

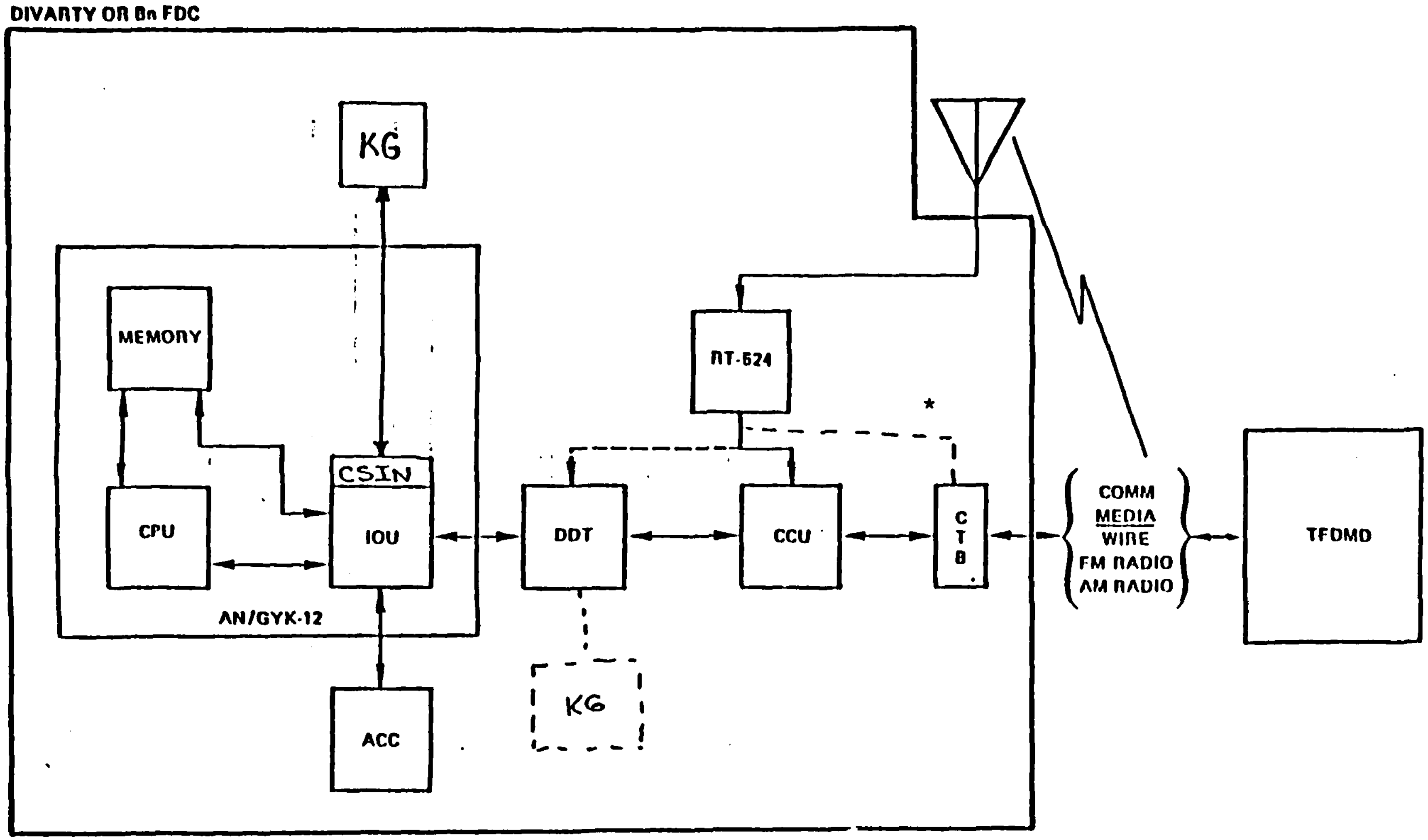
* Internal shelter radios are connected directly to CCU (Radio 9, 10).
External remote radios are connected to CTB through binding post (Radio 1-8).

Figure 7. TF-A Interface



* See note on figure 7.

Figure 8. TF-B Interface



*See note on figure 7.

Figure 9. TF-C Interface

different configurations have a common transmission link. This is indicated on the figures by the description COMM MEDIA, WIRE, FM RADIO, AM RADIO.

b. The signal produced for transmission across the serial link, wire or radio may be either 600±0.6 bps or 1200±1.2 bps. The modulation is a continuous phase frequency shift keying (FSK), where a 1200±1.2 Hz wave train represents a logical 1 and 2400±2.4 Hz represents a logical 0. For wire communications, the output level will be 0±2 dbm into 600 ohms.

c. The beginning of each serial message consists of a series of alternating ones and zeros used to achieve bit synchronization. These keytimes are operator-selectable and vary with different TACFIRE equipment.

d. The TF-A format may also use a 55-wire parallel data link. This interface is described in detail in appendix C.

2.2.2.2 Error Detection and Correction (EDC) Process

TACFIRE's EDC consists of 12/7 Hamming code which is applied to every seven-bit character in the cryptographic synchronization, message body, and message ending fields of a TACFIRE message. This code allows the correction of single-bit errors and the detection of double-bit errors within a character. (See appendix D for the Hamming code.) Messages may optionally be transmitted in the double block mode, where each 16-character block is transmitted twice. In double block mode, the first block is used unless it contains uncorrectable errors, in which case the second block is used. If the second block is unusable, the message is not acknowledged, causing retransmission of the message by the sender. EDC is part of layer 2, the data link layer, as defined in the ISO model.

2.2.2.3. Time Dispersal Coding Process

TACFIRE's time dispersal coding (TDC) is a logical scheme to minimize the occurrence of multiple bit errors. TDC is a bit interleaving technique where sixteen 12-bit characters are transmitted as a block. The first 16 bits transmitted are the least significant bits for each character. The remaining bits are transmitted in 16-bit groups consisting of one bit from each character until all bits have been transmitted. Figure 10 shows the order in which the bits for a 16-character block would be transmitted. TDC is part of the ISO model's layer 2, the data link layer.

2.2.2.4 Control Message Process

a. TACFIRE control messages ACK and NAK have unique formats determined by the configuration of the system. All ACK and NAK formats are 16 characters long. The first character of a control message contains the destination, the sixth contains the source, and the eighth contains an American Standard Code for Information Interchange (ASCII) ACK or NAK character. Figure 11 contains the details of the various ACK and NAK message formats. Figure 12 compares a communication header to a summary ACK format.

b. The TACFIRE SSA must have the ability to select an interface type during initialization in order for the correct control messages to be generated. The SSA should respond to a NAK condition by attempting automatic resynchronization where appropriate. When automatic resynchronization is not

		CHARACTER 1	CHARACTER 2	CHARACTER 3	CHARACTER 4	CHARACTER 5	CHARACTER 6	CHARACTER 7	CHARACTER 8	CHARACTER 9	CHARACTER 10	CHARACTER 11	CHARACTER 12	CHARACTER 13	CHARACTER 14	CHARACTER 15	CHARACTER 16
EDC CODE	P_5	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192
	P_4	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176
	P_3	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
	P_2	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144
	P_1	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128
ASCII CODE	b_7	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112
	b_6	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
	b_5	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
	b_4	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
	b_3	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
	b_2	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	b_1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

THE NUMBERS 1 THROUGH 192 CONTAINED IN THE MATRIX INDICATE THE ORDER BITS ARE TRANSFERRED TO THE COMMUNICATIONS NETWORK

Figure 10. TDC Bit Interleaving

	Character Position													
	1	2	3 4	5	6	7	8	9 10	11	12	13	14	15	16
FROM TACFIRE:														
ACK to TACFIRE, MLRS, BCS, LANCE	D	T	ACKN CODE	5	S	A/S	|X|	N N	Ck	SM	⅃	⅃	⅃	⅃
ACK to DMD, Firefinder	D	T	ACKN CODE	5	S	A	|X|	N N	N	N	⅃	⅃	⅃	⅃
ACK to VFMED	D	T	ACKN CODE	5	S	A	|X|	N N	Ck	SM	⅃	⅃	⅃	⅃
NAK to TACFIRE, MLRS, BCS, LANCE	D	T	AUTH/SI (Rec'd)	5	S	A/S	ⓧ	Exp SI	N	N	⅃	⅃	⅃	⅃
NAK to DMD, Firefinder	D	T	AUTH/SI (Rec'd)	5	S	A	ⓧ	Exp SI	N	N	⅃	⅃	⅃	⅃
NAK to VFMED	D	T	AUTH/SI (Rec'd)	5	S	A/S	ⓧ	Exp SI	Ck	SM	⅃	⅃	⅃	⅃
FROM MLRS, BCS, LANCE:														
ACK to TACFIRE	D	0	AUTH/SI (Rec'd)	5	S	A/S	|X|	Ck SM	⅃	⅃	⅃	⅃	⅃	⅃
NAK to TACFIRE	D	0	AUTH/SI (Rec'd)	5	S	A/S	ⓧ	Exp SI	Ck	Sm	⅃	⅃	⅃	⅃
ACK to DMD	D	0		5	S	A	|X|	⅃ ⅃	⅃	⅃	⅃	⅃	⅃	⅃
NAK to DMD	D	0		5	S	A	ⓧ	Exp SI	⅃	⅃	⅃	⅃	⅃	⅃
FROM VFMED:														
ACK to TACFIRE	D			5	S	A/S	|X|	Ck SM	⅃	⅃	⅃	⅃	⅃	⅃
NAK to TACFIRE	Never													
FROM DMD:														
ACK to TACFIRE	D			5	S	A	|X|	⅃ ⅃	⅃	⅃	⅃	⅃	⅃	⅃
NAK to TACFIRE	Never													

D = Destination T = Transmit Repeat Number ACKN CODE, AUTH/SI = Authentication 5 = ACK/NAK Message Type
S = Source A,A/S = Text ⓧ = NAK |X| = ACK ⅃ = End of Transmission N = Null
EXP SI, CK SM = Additional Text

Figure 11. ACK/NAK Formats

Communications Line Header--Received Message

1	2	3	4	5	6	7
Destination	Transmission repeat number			Message Type	Message Source	;

Authentication and Serialization

General Format of ACK/NAK

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Destination	TRN			5	Source										

Authentication and Serialization

1 - destination--from 6--source on received
2 - Transmission Repeat Number (TRN)--from 2--TRN on received
3, 4 - authentication and serialization--from 3--authentication and serialization on received
5 - binary 5 for control message type
6 - source of ACK from 1--destination on received
7 - "A" if unencrypted, "S" if encrypted
8 - ASCII ACK character or ASCII NAK character
9, 10 - null, checksum, EOT, or expected SI
11, 12 - null, checksum, or EOT

Figure 12. Field Comparison Between Communications Line Header and Control Messages

possible, the condition should be logged and the operator notified. The SSA should respond to a nonacknowledgement (no response) by generating retry transmissions for three tries. After the third nonacknowledgement, a channel fault should be logged. In the event of channel fault or an auto-resynchronization failure, it is desirable to provide an operator interface to allow TIS to use TACFIRE manual resynchronization techniques. The control message process is part of layer 2, the data link layer, as defined by the ISO model.

2.2.2.5 Subscriber Table Maintenance Process

a. The TIS TACFIRE SSA must maintain a TACFIRE-like subscriber table to communicate in the TACFIRE environment. Data must be stored by TIS for each simulated or live subscriber.

b. A minimal TIS subscriber table should consist of the entries shown in table II.

TABLE II. TIS SUBSCRIBER TABLE

PH SUB	TIS CHANNEL NUMBER
SEQ	SERIAL NUMBER
TRN	TRANSMIT REPEAT NUMBER

c. PH SUB is used in TACFIRE for physical subscriber addressing information. In TIS, the PH SUB fields would contain the communication channel number for a subscriber. The SEQ field would contain the next unused serial number for send and receive. The Transmit Repeat Number (TRN) field would store the most recently used TRN for each channel. The TIS software would maintain current TRNs for each channel under this scheme. Subscriber table maintenance provides physical address of service, which is part of layer 3 of the ISO model, the network layer.

d. Those layer 1 through 3 functions which are an integral part of the TACFIRE protocol have been discussed. All of these functions should be supported in a TIS TACFIRE SSA. Other areas exist which have definable real-time processes that are desirable but not mandatory in a TIS environment.

2.2.3 Real-Time Processes Optional for TACFIRE SSA

Some layer 4 through 7 processes should be supported in real time for a fully operational system but are less critical. Omission of these processes might cause error and warning messages but would not preclude message exchange.

2.2.3.1 Loop Test Process

a. The TACFIRE system transmits and responds to internal loop test messages generated automatically as a result of internal parameters. These messages are normally exchanged between the TACFIRE Fire Direction Center (FDC) and its remote subscribers. The loop test messages may ' ı once or at regular intervals. Figure 13 shows a sample loop test message. Full

implementation of the remote loop test process would require the functions described in table III.

```
1)  If VFMED initiates remote test with the following loop test message:

    Z00140
    MD;XMT2;TEST: 0 1 2 3 4 5 6 7 8 9

    TACFIRE responds with acknowledgement (ACK)
    00015ZSx

2)  If VFMED initiates remote test with the following loop test message:

    Z00240;
    MD;RCV2;TEST: 9 8 7 6 5 4 3 2 1 0

    TACFIRE generates and transmits a response:

    00014Z;R:7;SB:F/S/E/ / ;C:UN ;SG:1 ,1 ;DT:02,09/23/22;ID202; A:A;
    MD;RCV2:TEST: 9 8 7 6 5 4 3 2 1 0

    Z  30Ax
```

Figure 13. Loop Test Examples

The loop test process is used to verify that a valid end-to-end path exists between two given nodes and is logically a part of the ISO model layer 4. It is desirable but not necessary for message exchange to include this function in a TACFIRE SSA.

TABLE III. FUNCTIONS REQUIRED FOR LOOP TEST MESSAGE PROCESSES
Echo of Input Test Messages
Definition of Interval Timer
Generation of Test Messages
Logging of Test Messages

b. Appendix E describes the SYS;MISC and SYS;MDS, miscellaneous and message and diagnostic test messages, message formats which control the loop test message process in a TACFIRE system.

2.2.3.1.1 Echo of Input Test Messages

Some test messages received by the TIS should be echoed back to the originator while others should simply be acknowledged. Figure 13 illustrates examples of each case. The determining factor in items 1, 3, and 4 of figure 13 is the field before the TEST field, which contains either RCVn or XMTn. If

the TIS receives a message with that field containing RCVn, the source and destination should be switched and the message should be echoed on the channel it came from. A received message with XMTn in that field should be treated as a routine received message and should simply be logged and acknowledged.

2.2.3.1.2 Definition of Interval Time

The TACFIRE SSA must maintain an interval timer to emulate the TACFIRE test message process. In TIS this timer could be initialized from the initialization file. Alternatively, the SSA could extract the interval from the Remote Loop Test Interval (RLPI) field on an incoming SYS;MISC message. This message is described in appendix E. TACFIRE's legal range for this parameter is 0 to 59 minutes, with a default of 30 minutes.

2.2.3.1.3 Periodic Generation of Test Messages

The SYS;MDS message, described in appendix E, is used in TACFIRE to initiate various self-test features. If the RLOOP field is used, the remote loop test will run, causing the generation of a test message or messages. An entry of S will specify that a single test message be generated at the next expiration of the interval timer (discussed in paragraph 2.2.3.1.2). An entry of M in the RLOOP field will cause generation of multiple test messages, one for each expiration of the interval timer. The SSA could extract this information from incoming messages, or it could simply read an RLOOP parameter from an initialization file. The SSA could then generate test messages similar to those shown in figure 13 at the time-specified intervals.

2.2.3.1.4 Logging of Test Messages

Test messages received by TIS must be logged in the same manner as all incoming messages. The log file should also record any TIS-initiated test messages and all modifications to the RLPI and RLOOP parameters of the SYS;MDS message of appendix E.

2.2.3.2 Serialization and Validation Process

The TIS TACFIRE SSA must have the ability to validate messages. One method of accomplishing this is serialization through use of the SEQ parameter in the TIS subscriber table. SEQ would be incremented for each message transmitted on a channel. The SEQ value from the table would be inserted into the communications line for each message transmitted. TIS must insert an updated transmit repeat number in the communications line of retries due to nonacknowledgement from the SUT. Received messages would be acknowledged and logged without regard to serialization. The TACFIRE serialization technique should be employed by TIS as opposed to an authentication matrix. Although serialization and validation logically fit into layer 5, the session layer of the ISO model, TACFIRE has forced this function to become part of the criteria for message exchange at level 3. This information could be included in prescripted messages, assuming an error-free transmission line.

2.2.3.3 Application Messages

Application messages correspond to layer 7 in the ISO model. Most application messages in TACFIRE can be supported by prescripting during the pre-test phase. Real-time processing at the application level may be

considered as event processing. A tactical event may be described in terms of specific message sequences. Those messages may be arbitrarily generated in a predetermined sequence to represent the event. Messages which are difficult to generate during pre-test or which are time critical and unpredictable during real-time must be supported by real-time process simulation if they are to be tested.

2.2.3.3.1 FM;RFAF (Fire Mission; Request For Additional Fire) Event

Figure 14 shows a message sequence which could represent a tactical event. By defining the event parameters to include only the link between battalion (BN) and division artillery (DIVARTY), the sequence FM;RFAF, FM;MFR, FM;EOM (Fire Mission; Mission Fired Report, Fire Mission; End of Message) could represent a BN FDC. A stream of scripted messages from the TIS (BN) could be transmitted to the division TACFIRE computer. In response to an FM;RFAF from division, the simulated BN FDC would generate FM;MFR and FM;EOM and insert them into the message stream. This message stream generated in real time would include data representing the action of the forward observer (using a TFDMD) and fire unit (using a VFMED) controlled by the TACFIRE BN FDC. Because scripted messages could be created easily to give the same results as the real-time event processing, this application layer process could be supported without the need for real-time process simulation.

2.2.3.3.2 SYS;FORM (SYSTEM;FORMAT) Event

Defining the parameters of the event differently would lead to different real-time processing requirements. If TIS were representing the BN FDC and its link to the fire support officer (FSO), figure 15 might realistically describe the event. The event represented by figure 15 would be the update of zone of responsibility parameters at FDC by the FSO. The messages involved are SYS;FORM and SPRT;ZNE. These message formats are described in appendix E. To support this configuration, TIS would need the capability of responding to a SYS;FORM request for format by extracting a blank format from the message format library (MFL) and inserting it into the message stream. Response to SYS;FORM would be difficult to support with scripted messages. To support SYS;FORM requests by prescripting the response, the exact time of the request must be known in order to avoid a situation wherein a response is sent before the corresponding request. The possibility exists in a scripted environment for other message loading factors to affect the rate at which the scenario is executed, thus causing messages to be transmitted out of sequence or at a time other than planned. For this reason, real-time generation of the blank message formats is an attractive solution to support the SYS;FORM process. The SYS;FORM process fits the ISO model definition for layer 6, the presentation layer.

2.2.3.3.3 Message of Interest Processing

a. One TACFIRE process which would create a high volume of message traffic is message of interest (MOI) processing. In a TACFIRE configuration, a subscriber may designate specific message types to be handled by the MOI process. When the computer (for example, BN FDC) processes a message, the MOI process causes a copy of the message to be forwarded to those subscribers whose MOI criteria include the message. Messages may be designated as MOI for input, output, or both. Action codes A, B, or C are associated with messages of interest. Table IV describes the effect of these action codes.

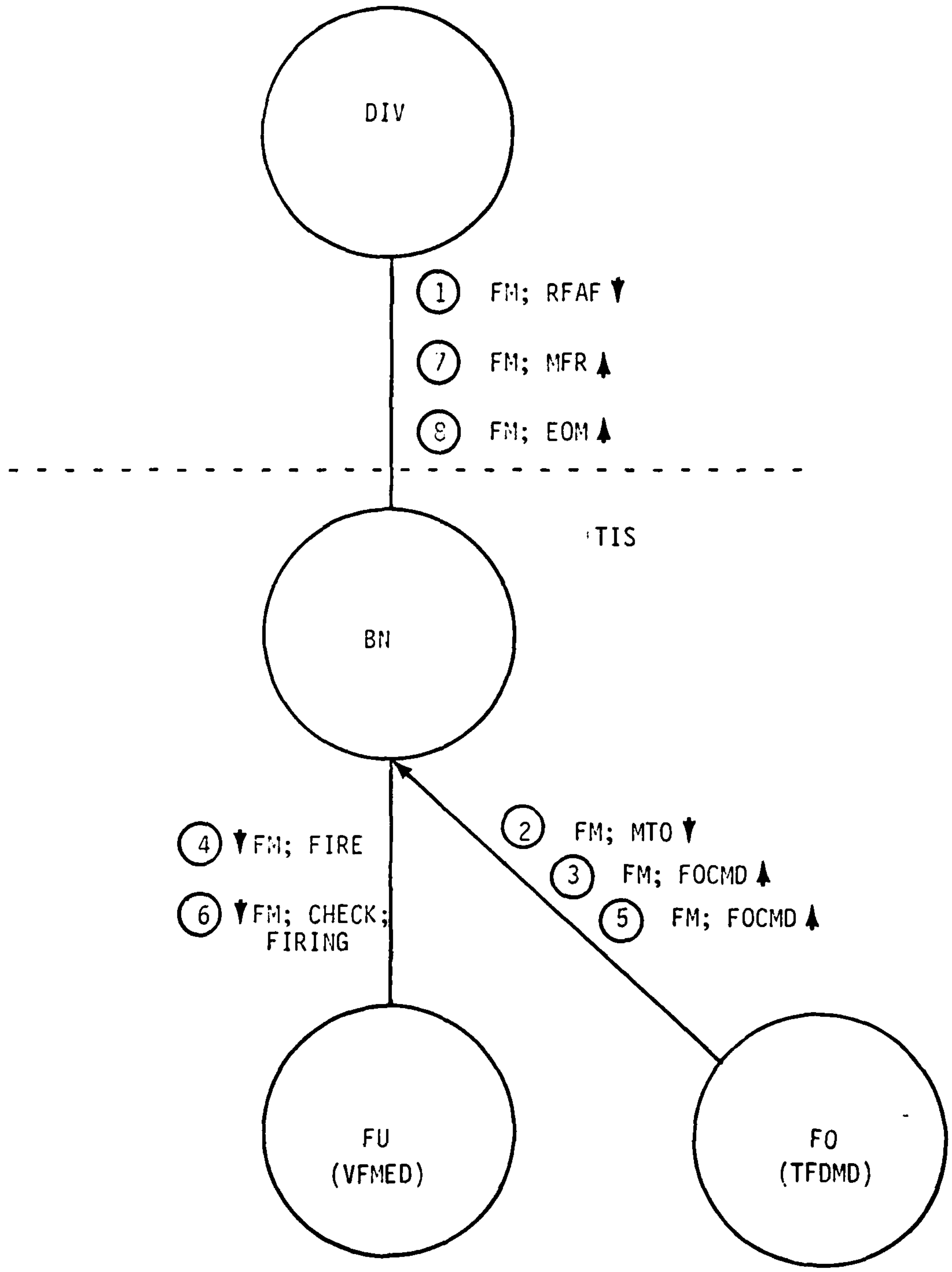


Figure 14. Tactical "Event": TACFIRE Fire Mission

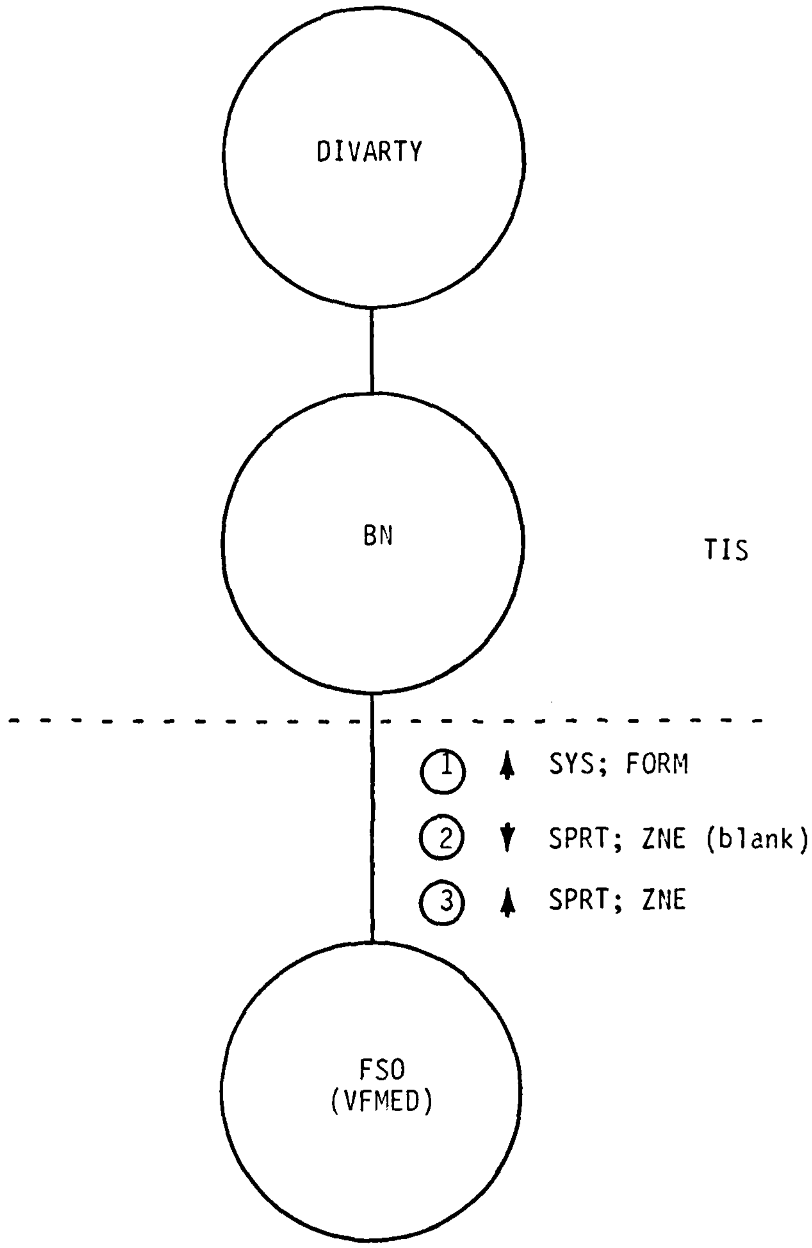


Figure 15. Tactical "Event": TACFIRE SYS;FORM

TABLE IV. ACTION CODES

ACTION CODE	RESULT
A	Forward all messages
B	Send if from my observer or Send if in my zone of responsibility
C	Send if only from my observer

b. ITIS support for MOI processing which relied entirely upon prescripted messages would be extremely difficult. The scenario designer would be required to examine all messages manually to check for the MOI criteria and to create duplicate copies of those messages which met them. To support MOI processing in TIS during real time, the SYS;FSO message would be examined to extract MOI criteria. Alternatively, the MOI criteria could be established at initialization. An MOI process would require an internal file containing information on zones of responsibility and observer assignments. The output of the process would be real-time insertion of copies of messages from the scenario which met MOI criteria in the appropriate message streams. All real-time-generated messages of interest would be logged as they are transmitted. This layer 4 (transport layer) process would provide a means of increasing network traffic, which would be useful in support of saturation testing.

2.3 MANEUVER CONTROL SYSTEM

The MCS real-time processes were compared to the ISO model in figure 4. The low-level protocol routines correspond to ISO layers 1, 2, and 3. End-to-end accountability is part of ISO layer 4. Remote filing could be compared to the ISO layer 5. Abridging and message format definition fit into layers 6 and 7. Like TACFIRE's, MCS processes can be categorized as required, desirable, and scriptable (figure 1).

2.3.1 Protocol Interface Routines Required for an MCS SSA

For MCS, as with TACFIRE, the layer 1, 2, and 3 processes are required to support basic message exchange. In MCS, the required processing for the SSA includes:

Physical Interface
Error Detection and Correction
Time Dispersal Coding
Autodial
Message Forwarding

2.3.1.1 Physical Interface

MCS may exchange data over the physical interface described for TACFIRE (paragraph 2.2.2.1). Additionally, MCS supports interconnection through a conditioned diphase modem at bit rates of 8K, 16K, and 32K. The conditioned diphase modem supports a selectable key time from 1 to 99 seconds.

2.3.1.2 Error Detection and Correction Process

MCS's EDC consists of a 12/7 Hamming code which is applied to every seven-bit character in an MCS message. This code allows the correction of single bit errors and the detection of double bit errors, within a character. See appendix D for the Hamming code. Messages may optionally be transmitted in the double block mode, where each 16-character block is transmitted twice. In double block mode, the first block is used unless it contains uncorrectable errors; in which case the second block is used. Some service messages will be triple blocked to assure their receipt. If the third block is unusable, the message is not acknowledged, causing retransmission of the message.

2.3.1.3 Time Dispersal Coding Process

MCS's TDC is a logical scheme to minimize the occurrence of multiple bit errors. TDC is a bit interleaving technique wherein twelve 16-bit characters are transmitted as a block. The first 16-bit characters transmitted are the least significant bits for each character. The remaining bits are transmitted in 16-bit groups consisting of one bit from each character until all bits have been transmitted. Figure 10 shows the order in which the bits for a 16-character block would be transmitted.

2.3.1.4 Autodial

The MCS has the capability to use automated telephone dialing equipment. The originating node has the ability to seize the line, dial a distant node, sense line status, and transmit messages. The receiving node senses an incoming call, seizes the line, and receives messages. Both the Tactical Computer Terminal (TCT) and the Tactical Computer System (TCS) include a 0-29 digit telephone number in the node descriptions defined at initialization. TIS support for the autodial function would require storage of an operator-entered telephone number for each node and physical interface such as the 3614 switchboard or the AN/TTC-38 telephone central office.

2.3.1.5 Message Forwarding

The MCS is capable of forwarding incoming messages. At initialization, the operator associates each logical node address with a physical channel number. If a TCT or TCS receives a message addressed to another node, the address is checked against the list of valid destinations. If a match is found, the message is forwarded to the addressee. TIS support for message forwarding could be provided by the addition of a table linking logical node addresses to channel numbers. The SSA would check each incoming message to determine whether the logical addressee was correct for the receiving channel. If the two did not match, the address would be checked against the SSA's destination table. The message would be forwarded if a match were found; otherwise, an error message would be generated.

2.3.2 Real-Time Processes Optional for MCS SSA

The layer 4 through 7 processes described in the next few paragraphs are optional in the implementation of the MCS SSA. Without these processes in the TIS, the SUT may experience some error conditions, but message exchange would be possible between the TIS and MCS.

2.3.2.1 End-to-End Accountability Processing

a. The MCS has the ability to request end-to-end accountability for any message. This feature provides the originating station with a positive response for use in determining whether a relayed message successfully reached the addressee. When the addressed node successfully receives a message requiring end-to-end accountability, it generates an end-to-end acknowledgement (E/E ACK) addressed to the originator of the message. In the event of unsuccessful relay, an end-to-end negative acknowledgment (E/E NAK) will be generated by the relay node at which local acknowledgment failed. This E/E NAK is sent back to the message originator and may then be used to determine where the fault occurred. This process works as shown in figure 16.

b. The message depicted in this figure is originated at node 1 and is addressed to node 5. Each node first attempts to transmit the message along the line on its primary path. If the message is not acknowledged, the node attempts its secondary path. If all secondary paths also fail, the last node which successfully received the message originates an E/E NAK and sends it back to the node that originated the process, in this case node 1. If the message does reach node 5, node 5 is responsible for originating an E/E ACK to be transmitted back to node 1.

c. For the MCS SSA to have the capability to emulate any of the nodes in this configuration, it must be able to handle end-to-end accountability for this processing. The TIS must decode the incoming message to determine whether end-to-end accountability had been requested. If it was requested, the SSA would use information provided by the scripted scenario to determine the appropriate response. Responses would include origination of service messages such as an E/E ACK, origination of an E/E NAK, or no response.

2.3.2.2 Remote Filing

a. An operator of any MCS node has the option of filing a message at any valid destination node. The destination node has the option of filing this message or sending a "request denied" message back to the originating node. When a message has been filed remotely at a node, the filing node has the responsibility to support requests for retrieval or deletion of the message. The filing node can either reject these requests or process them. If the autoprocessing feature is selected, remote retrieval will take place with no operator intervention. Associated with this filing capability is a directory of messages filed which must be provided to the originating station upon request. The MCS Remote Request (RR) message supports the functions listed in table V.

b. To support testing of the MCS RR function, the SSA must have the capability of generating responses to these MCS messages. Because the messages that would be filed and retrieved would originate at the SUT, very careful and meticulous scripting of a scenario would be required to accomplish testing of remote requests without real-time processing.

c. An SSA real-time capability to support RR could be implemented in two ways. The first option would simulate the actual filing and retrieval of

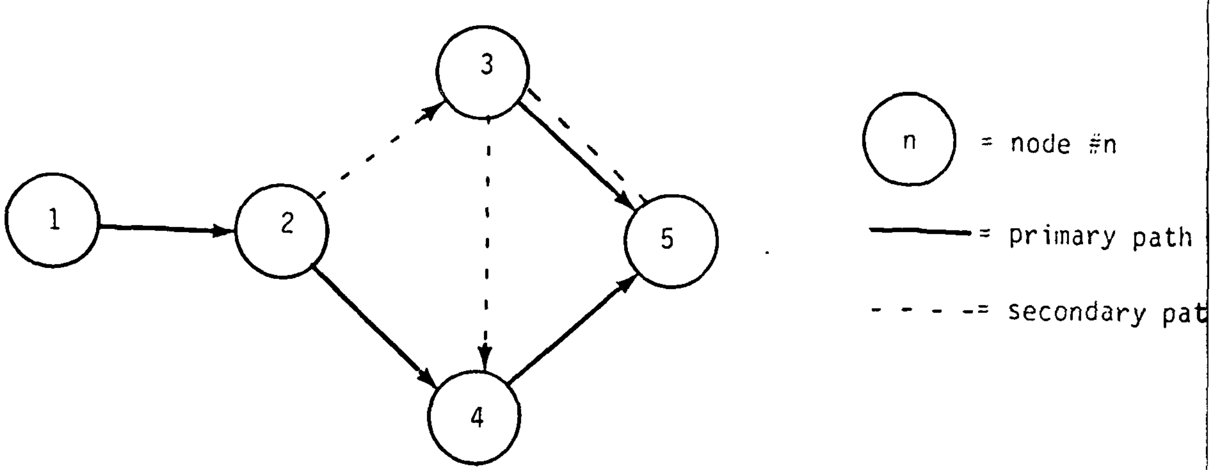


Figure 16. Sample Network Topology Illustrating End-to-End Paths

TABLE V. MCS MESSAGES SUPPORTED BY RR MESSAGE FORMAT
Remote Filing
Remote Retrieval
Remote Deletion
Request Denied

messages. This option would require support of at least a minimal DBMS capability to store incoming messages. Subsequent retrieval requests would result in the SSA retrieving the stored data and generating the proper blank message format to transmit data. The message would then be inserted into the message stream being transmitted to the SUT.

d. The second option for support of remote filing is much simpler to implement but would not provide as complete a set of options for stimulation of the SUT. This method would simply cause the TIS to transmit a request denied message or a canned message in response to all remote filing, remote retrieval, and remote deletion requests. This response would cause the sending MCS operator to take other action as directed by the scenario.

2.4 Test Item Stimulator

The transportable (van-mounted) TIS supports three operational functions used to perform DT of C^3I systems:

- Pre-test scenario prepartion.
- Real-time SUT stimulation.
- Post-test data reduction and analysis.

2.4.1 Pre-Test

The test scenarios that drive the real-time SUT stimulation are generated interactively through the pre-test function. These scenarios are composed of:

a. Command messages. These messages direct the real-time TIS activity, including:

- Loading an SSA.
- Starting the test.
- Checkpointing the test.
- Restarting from a checkpoint.
- Adding messages during the test.

- Deleting messages during the test.

- Modifying parameters controlling the execution of the real-time code (SSA).

b. Pre-scripted messages. These are the tactical messages that are sent to the SUT without major modification. These include both character-oriented and bit-oriented messages.

c. Real-time messages. These messages contain information used to control the real-time generation of message streams for transmission to the SUT.

d. Response Messages. These messages are stored in a response table. Messages from the SUT are compared with the table and if a match is found, the corresponding response is transmitted back to the SUT.

e. Test notes. These messages are logged along with the real-time message exchange to provide documentation for later use during post-test processing.

2.4.2 Real-Time

a. The real-time function provides the interface for stimulating and monitoring the SUT. The real-time function processes both scenario and operator-entered messages, producing a message stream to stimulate the SUT. The resulting message exchange is logged for later processing. The protocol handlers, formatters, and interface elements dealing with a specific protocol are collectively referred to as a SSA. Figure 17 depicts the data flow between the functional components of an SSA.

b. Scenario based and operator-entered messages driving the real-time processing are scheduled through the event reader. Command messages are routed to the SSA control process, where they modify the test execution. Pre-scripted messages are sent directly to the transmit process, which transmits data to the SUT and logs the transmission. Real-time messages and response messages are routed to the real-time message generation and response handling processes, which in turn, send transmittable messages to the transmit process. The receive process logs the SUT messages received and sends the received data to the response handling task, possibly triggering a response. Test notes are displayed to the operator and routed to the logging process.

2.4.3 Post-Test

Post-test processing of the log files generated during testing produces statistical reports on message content and end-to-end system throughput.

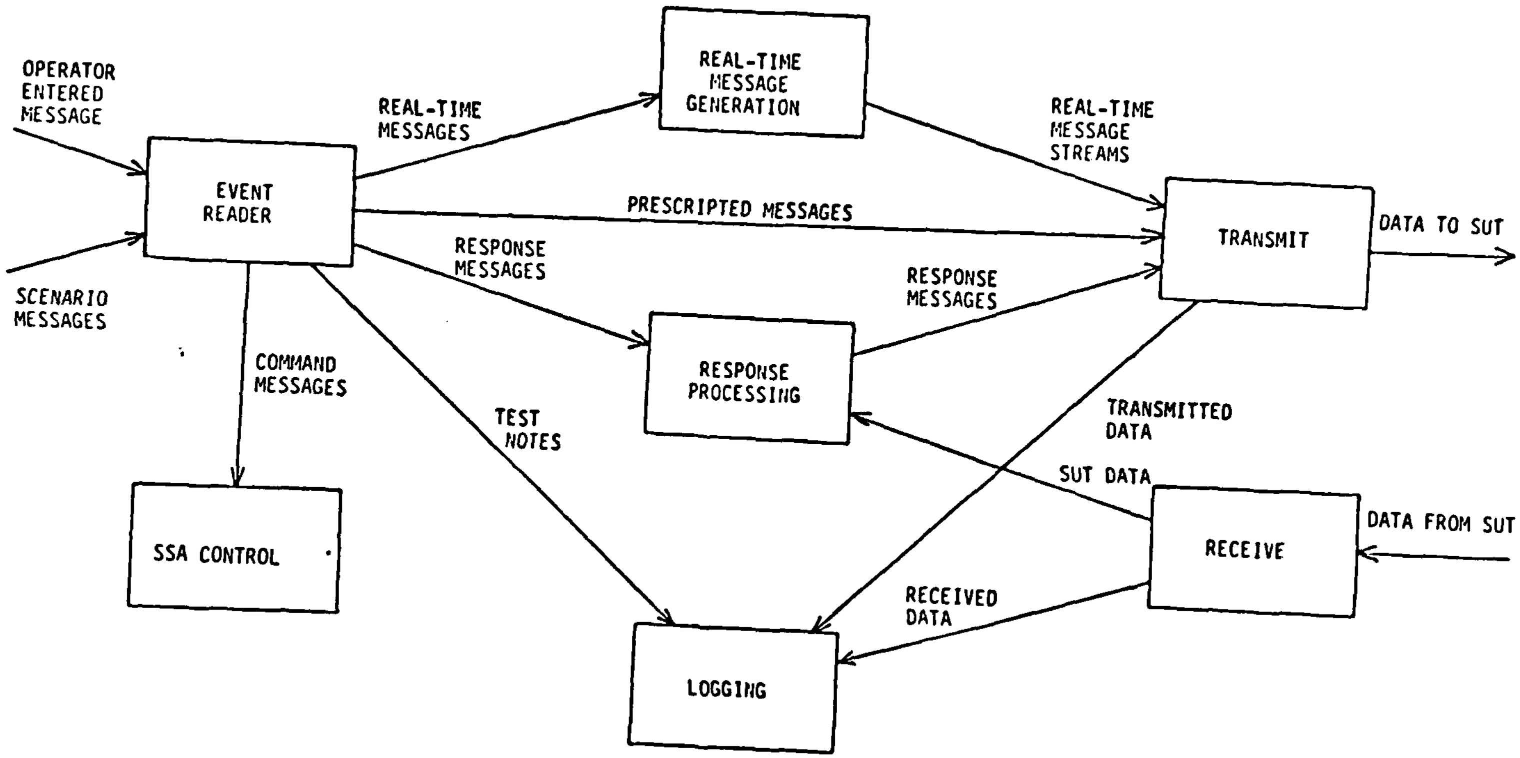


Figure 17. System Specific Applique (SSA) Data Flow

APPENDIX A

METHODOLOGY INVESTIGATION PROPOSAL

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January 1983

METHODOLOGY INVESTIGATION PROPOSAL

1. TITLE. Real-Time Message Process Simulation Capability

2. CATEGORY.
   a. Thrust Areas.
      (1) VISTA
      (2) DC^3I
      (3) SMI
   b. Sub-Areas.
      (1) Software
      (2) Interoperability

3. INSTALLATION. US Army Electronic Proving Ground, Fort Huachuca, Arizona 85613

4. PRINCIPAL INVESTIGATOR. Leslie F. Claudio, Software and Automation Branch, STEEP-MT-DA, AUTOVON 879-1879.

5. STATEMENT OF THE PROBLEM. In testing message-driven systems which have control functions, a method is required for simulating, in real-time, the responses of the controlled resources represented by the message stream from a Test Item Stimulator (TIS). Current methods of testing using the Interim TIS (ITIS) or the TIS require that all simulation messages be composed off-line prior to the real-time test. This constraint makes test of real-time control functions in a System Under Test (SUT) difficult if not impossible.

6. BACKGROUND.

a. History. The Army is developing a large number of automated tactical command, control, communications, and intelligence (C^3I) systems. These systems and their many interfaces with each other rely on digital message exchange for input, output, and intra-system data exchanges. Their performance is frequently manifested as data in an output message or display and their inputs as digital messages from an operator device, a sensor, or an inter-operating system. To stimulate and acquire the responses from such systems, devices called test item stimulators are used to apply test message streams which have been specifically designed to evoke the function of which the SUT is supposed to be capable. An interim or prototype TIS capability exists and is being used to support DT. TIS' compatibility with other USAEPG system test instrumentation are included in the MAINSITE equipment acquisition.

b. Progress. This is a new project for FY 83.

7. GOAL. To develop methods of generating, in real-time, information that can be inserted in test message streams that would have been performed by a system controlled by outputs from the SUT.

8. DESCRIPTION OF INVESTIGATION.

a. This investigation will develop specifications for modification to the basic ITIS and TIS system being acquired as part of the MAINSITE acquisition.

b. The US Army Electronic Proving Ground will conduct the investigation as follows:

(1) Identify those Army C^3I systems which will have real-time control functions which cannot be tested using pre-composed test message streams and identify the processes that would have to be simulated and the information that would be required by output from those processes.

(2) Based upon the design of the ITIS and MAINSITE TIS system, identify feasible changes that should be made to the ITIS/TIS requirements and design documentation to accommodate an adequate real-time message process simulation capability.

c. Investigation Schedule.

```
MILESTONE/PHASE                                          SCHEDULE

                                        FY 83 (Qtrs)        FY 84 (Qtrs)
                                       1   2   3   4       1   2   3   4

Identification of control functions      X   X
  in Army C3I systems
Identification of essential control        X   X             X
  processes
Identification of control process              X    X
  simulation information requirements
FY 83 report                                            X
Engineering change proposal(s) to              X    X        X   X
  ITIS/TIS requirements documents
Engineering change proposal(s) to                   X   X      X          X
  ITIS/TIS design documents
Final report                                                              X
```

d. This investigation will result in the definition of procedures for simulating the responses of systems being represented by ITIS/TIS message stream. The definition will be in a form so that it may be used directly by the ITIS/TIS system maintainer to purchase the services required to make the changes.

e. Environmental Impact Statement. The execution of this task will not have an adverse impact on the quality of the environment.

f. Health Hazard Statement. No health hazards are anticipated.

9. JUSTIFICATION.

a. Mission and Impact Statements.

(1) Association with mission. USAEPG's primary mission is to conduct DT of C^3I equipment and systems. Most of these systems employ digital messages to exchange information. This task is required to enable the test of those C^3I systems which have real-time control functions.

(2) Present Capability, Limitations, Improvement, and Impact on Test Programs if not Performed in the Proposed Fiscal Year. The present capability

requires that all test messages be composed and validated prior to the start of a real-time test. Processes that a SUT might be controlling may currently only be reflected in the message stream if they are simple, relatively slow, and if the behavior of the SUT is predictable enough that synchronization of the input stream and outputs is not lost during the test. A method is required to permit the stimulus messages to reflect information changes that a SUT would expect in response to its outputs. If this investigation is not completed, controlled, repeatable, and statistically significant, tests of the major Army C^3I systems that have control functions will not be possible.

b. Dollar Savings. The savings over the alternative of not performing those tests which cannot be accomplished with the present method cannot be computed. Most C^3I systems will fall in this category by 1983.

c. Workload. There are five executive systems in the Army Command Control System. Each has or will have interfaces to many subordinate or inter-operating systems. The interface tests alone to be accomplished in the 1985 to 1995 timeframe will number in the hundreds. Systems representative of those to be tested include:

System	TECOM Priority	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88
RPV			DT-II				
PJH				DT-II	DT-II		
JTIDS			DT-II				
SHORAD						DT-II	
ATHS		DT-II					
AFATDS							DT-I
ASAS				DT-I	DT-II		

d. Recommended TRMS Priority. One.

e. Association with Requirements Documents.

(1) MAINSITE TIS requirements documents will be the baseline to which the products of this task will be referenced.

(2) The methodology resulting from this task will not be tailored exclusively to the requirements of any one specific SUT, but will be designed to be generally applicable to Army C^3I systems.

10. RESOURCES.

a. Financial.

(1) Funding Breakdown.

	Dollars (Thousands) FY 84 In-House	Out-of-House
Personnel Compensation	15.0	
Travel	2.0	
Contractual Support		162.5
Material & Supplies	0.5	
Subtotals	17.5	162.5
FY Totals	180.0	

(2) Explanation of Cost Categories.

(a) Personnel Compensation. Cover in-house labor costs for the principal investigator and other in-house project support personnel.

(b) Travel. Travel is required to conduct the survey of current technology and to coordinate the tasks with other Government agencies.

(c) Contractual Support. Approximately 90 percent of the work will be accomplished by a contractor under an existing service contract.

(d) Materials and Supplies. Incidental supplies will be required to support the investigation.

b. Anticipated Delays. No delays are anticipated at this time.

c. Obligation Plan. (FY 84)

	FQ 1	2	3	4	TOTAL
Obligation Rate (Thousands)	150	10	10	10	180

d. In-House Personnel.

(1) Requirements.

		FY 84 Manhours	
Type	Number	Required	Available
Electronic Engr GS-0855	1	600	680

(2) Resolution of Non-Available Personnel. Not applicable.

11. INVESTIGATION SCHEDULE.

```
                     FY 83                                 FY 84
               O N D J F M A M J J A S            O N D J F M A M J J A S

                                                              .
In-House       - -                   - -          -           -       - R

                 . . . . . . . . . . .          . . . . . . . . . . .
Contract         - - - - - - - - - -              - - - - - - - - - - -
```

Symbols

- - - Active investigation (all categories)
. . . Contract monitoring (in-house only)
R   Final report due at HQ, TECOM

12. ASSOCIATION WITH TOP PROGRAM. It is not anticipated that this investigation will result in a new Test Operations Procedure.

FOR THE COMMANDER:

MELVIN FOWLER
LTC, SigC
Director of Material Test

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APPENDIX B

DEFINITIONS AND ACRONYMS

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ACC = Artillery Control Console.

ACK = Acknowledgement.

ASAS = All Source Analysis System.

ATDL-1 = Automated Tactical Data Link. Message format used by TSQ-73 and IHAWK.

BAS = Battlefield Automated System. A term sometimes used to describe tactical C^3I systems.

Baud = Data transfer rate, bits per second for binary singals. (After J.M.E. Baud.).

BRTS = Basic Real-Time System

C^2 = Command and Control.

C^3 = Command, Control, and Communications.

C^3I = Command, Control, Communications, and Intelligence.

CCU = Communications Control Unit.

CDP = Conditioned diphase. A conditioned diphase modem uses phase shifts to distinguish between a one and a zero in digital data transmission.

CIM = Communications-Interface Module. The CIM is a functional subsystem of a TCS.

COM System = Character-oriented message system.

Control message = TACFIRE; generic for ACK or NAK type messages.

CSIN = COMSEC Interface.

CTB = Communications Terminal Box.

DT = Development Test

DIVARTY = Division Artillery.

DDT = Digital Data Terminal.

DoD = Department of Defense.

EDC = Error detection and correction.

E/E = End-to-end, having to do with communication between sending and destination nodes in a network environment, not limited to an intermediate relay in the total path.

EDB = End of Block

FDC = Fire Direction Center. TACFIRE term.

FO = Forward Observer.

FSE = Fire Support Element.

FSK = Frequency-shift keying. An FSK modem uses distinct frequencies to distinguish between a one and a zero during digital data transmission.

FSO = Fire Support Officer. TACFIRE term.

FU = Fire Unit.

HIU = Host Interface Unit

IOU = Input/Output Unit.

ISO = International Standards Organization.

ITIS = Interim Test Item Stimulator. Digital message test driver initially used in testing MCS.

ITR = Input-to-Register

JTIDS = Joint Tactical Information Distribution System

KG = Keying Generator.

MCS = Maneuver Control System.

MED = TACFIRE message entry device.

MFL = Message Format Library. Part of the data base of a TIS which defines the message formats used to communicate/with a SUT.

MOI = Message of Interest. Designation which may be given to TACFIRE messages to indicate special processing and routing is desired.

NAK = Negative acknowledgement.

PJH = Position Location Reporting System/JTIDS Hybrid

RLPI = Remote Loop Test Interval

Service message = MCS; generic for ACK, E/E ACK, or E/E NAK type messages.

SSA = System-Specific Applique. The component of the general purpose TIS which must be tailored to the specific characteristics of the SUT.

SUT = System Under Test. Test item, usually a C^3I system, to be exercised by means of the TIS.

SYNC = Synchronization.

TACFIRE = Tactical Fire Direction system; message format used by TACFIRE system for tactical data communications; includes TF-A, TF-B, and TF-C subsets.

TCS = Tactical Computer System. A TCS is a minicomputer which may act as a node in an MCS network. A TCS will support multiple analyst consoles which are also addressable nodes in MCS.

TCT = Tactical Computer Terminal. A TCT is a microcomputer which may act as a single node in an MCS network.

TDC = Time dispersal coding.

TF-A, B, C = TACFIRE interfaces; type A, B, and C.

TIS = Test Item Stimulator. Successor to the ITIS system.

TRN = Transmit Repeat Number. Field used in TACFIRE messages.

USAEPG = U.S. Army Electronic Proving Ground

VFMED = Variable-format message-entry device. Part of TACFIRE.

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APPENDIX C

TACFIRE IOX INTERFACE STRUCTURE

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1. Host Interface Unit (HIU) Fire Direction Center (FDC) Interfaces Requirements. The functional interface between the FDC and the HIU shall take place over the device bus of the FDC AN/GYK-12 computer. The HIU shall emulate those electrical and functional characteristics of a Digital Data Terminal (DDT) which are necessary to facilitate data transfer between the FDC and the terminal. In this appendix, the AN/GYK-12 shall be referred to as the computer.

1.1 Computer-to-HIU Interface Characteristics. The data and handshake lines employed in the computer-to-HIU interface shall be as shown in figure C-1.

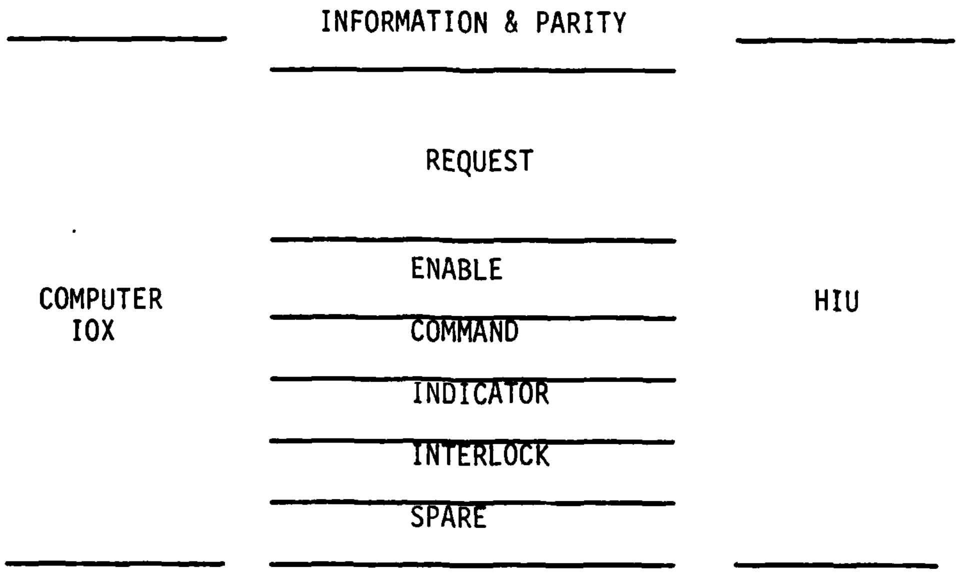


Figure C-1. HIU-to-Computer Interface

1.1.1 Input/Output Communication Channel. The HIU shall communicate with the computer via one of three input/output exchanges (IOXs). The transfer of information shall be over a cable containing 27 twisted-pair lines. The signal line shall use transformer-coupled circuitry and shall be terminated at each end.

1.1.2 The lines and signals of the I/O communication channel (figure C-1) shall be defined as follows:

a. Information Lines (Bidirectional, Bussed). Nine lines shall be used for the purpose of transmitting information between the HIU and the computer as follows:

The information in this appendix is derived from appendix III of reference 19 (see appendix F).

1. Data Signals. Information lines 1 through 7 shall contain the 7-bit ASCII data character. Information line 0 is not used (set to 0) for ASCII data transfer; information line P shall contain the byte odd parity bit. A single character is transmitted as a result of a data transfer sequence.

2. Address Selection. Eight information lines shall be used to indicate which communication channel is being selected. A channel is selected by the individual channel line being pulsed coincident with an Enable or Command signal. The HIU is selected when information line 0 or 1 is pulsed.

3. Command Control. The information lines shall be used to signify specific operational actions to be performed by the HIU, subsequent to the address selection phase. The information appearing on the information lines shall specify which of the operations is to be performed (refer to table C-I).

b. Request Lines (to Computer). The communication channel shall have eight Request lines, with two Request lines assigned to each circuit, one line for transmit (odd-numbered Request line) and one line for receive (even-numbered Request lines). Without the HIU present these lines are used to indicate which device on the IOX bus is requesting service, and whether the request is for transmit or receive. The HIU shall use lines 0/1 to indicate to the computer to which circuit the message being transferred is associated. (Table C-II shows the relationship.)

c. Enable Line (from Computer). This signal shall be used in conjunction with the information lines to perform address selection. When this signal appears, the following transfer of information shall have data flowing to or from the computer, or it shall be an HIU interrupt. This signal shall also be used in conjunction with the Command line to signify a Master Reset.

d. Command Line (from Computer). This signal shall be used in conjunction with the information lines to perform address selection. When this signal appears, the following transfer of information shall be a command operation as shown in table C-I. Further information flow shall be predicated upon the actual command issued. This signal shall also be used in conjunction with the Enable line to signify a Master Reset.

e. Indicator Line (to Computer). The Indicator line shall be used for two purposes: to acknowledge receipt of a special command and to initiate a device interrupt.

f. Interlock. The Interlock signal shall be routed through the HIU to ensure cable connection integrity.

2. <u>I/O Operations</u>. The host interface unit (HIU) shall support the command and data transfer protocols described in the following paragraphs.

The HIU shall not support the following computer I/O modes:

TABLE C-I. COMMAND FORMAT ON INFORMATION LINES

BITS PRESENT DURING COMMAND PHASE	FUNCTION
0 AND 3	DEVICE COMMAND (DEV)
0 AND 4	OUTPUT FROM REGISTER (OFR)*
0 AND 5	INPUT TO REGISTER (ITR)
0 AND 6	END OF BLOCK (EOB)
0 AND 7	DEVICE STOP

* NOT USED BY HIU

TABLE C-II. REQUEST LINE ASSIGNMENTS FOR EACH IOX

CHANNEL SELECT SWITCH SETTING	REQUEST LINE	
	RECEIVE	TRANSMIT
0/1*	0	1
2/3	2	3
4/5	4	5
6/7	6	7
REMOTE'	0	0

' PERIPHERAL EQUIPMENT INTERFACE: COMPUTER NOT CONNECTED TO INTERFACE COM APP LINES SHORTED.

* HIU NOT FRONT PANEL SWITCH SELECTABLE HARDWIRED TO 0/1.

a. Alarm mode

b. Burst mode

2.1 Command Recognition. The HIU shall recognize that a command sequence is in progress by sensing a signal on the command twisted-pair signal line between the computer and the HIU.

2.1.1 Command Sequence. The timing for a Command Sequence shall be as shown in figures C-3 and C-5 through 7. Table C-III and figure C-2 define the notations used in the timing diagrams. The Command Sequence shall consist of the following operations:

a. The HIU senses a Command signal on the transmit command line.

b. The HIU shall accept the address character on the eight information lines.

c. If the parity is proper and the control character is a true control character, the HIU shall generate an acknowledgement of the control sequence by generating a signal on the Indicator line within 10 microseconds after receipt of the Device Command signal.

2.1.2 Command Operations. The HIU shall determine the particular command from the computer by sensing the eight information lines and recognizing the character present. The commands supported shall be those specified in table C-I and shall be present on the eight information lines in conjunction with the Command line.

2.1.3 DEV Operation. The DEV command consists of an address selection phase, employing the Command line, a device control phase with information lines 0 and 3 activated, followed by a single byte of information which is used by the HIU for control purposes. The HIU commands are defined in table C-IV. The HIU shall acknowledge receipt of this command sequence by activating the indicator line after receiving the data byte. The timing for this command sequence is shown in figure C-3. If the HIU is commanded to enter a state it is presently in, the HIU shall not acknowledge the command.

2.1.4 ITR Operation. The Input-to-Register (ITR) sequence consists of an address selection phase employing the Command line, followed by a device control phase employing information lines 0 and 5, followed by one data byte generated by the HIU. The contents of the data byte shall be as specified in figure C-4. Timing for this instruction is shown in figure C-5.

2.1.5 EOB Operation. The End-of Block (EOB) sequence consists of an address selection phase employing the Command line, followed by a device control phase employing information lines 0 and 6. If the HIU is to interrupt the computer, it may send a Request any time after recognizing the device control information. The timing for this sequence is shown in figure C-6.

2.1.6 Stop Operation. This operational sequence consists of an address selection phase employing the Command line, followed by a device control phase employing information lines 0 and 7. The sequence is generated by the computer when an illegal or erroneous condition occurs as related to the HIU. When the HIU detects this operation is shown in figure C-7.

TABLE C-III. IOX BUS TIMING PARAMETERS

PARAMETER REMARKS	SYMBOL	MIN	TYP	MAX	UNIT
HIU RESPONSE, CONTROL WORD ACK	t_{CA}			5	μs
COMPUTER INTERVAL, DATA OUT	t_{DO}	1.7	3.0	7.2	μs
HIU REQUEST TIMING	t_R	0.4		1.3	μs
COMPUTER RESPONSE TO REQUEST (HIGHEST PRIORITY)	t_E	0.240		31	μs
HIU RESPONSE, DATA IN EOB	t_{DI}	0.4		5.0	μs
SEQUENCE TIMING					
I: HIU TO COMPUTER	$t_{EOB(I)}$			6.3	μs
O: COMPUTER TO HIU	$t_{EOB(O)}$			1.3	μs
HIU RESPONSE	t_{ID}	0.57		1.5	μs
HIU RESPONSE, INTERRUPT REQUEST AFTER EOB	t_{ER}	≥ 0		1.5	μs
HIU INTERRUPT TIME AFTER ENABLE		0		1.5	μs

* THE SYMBOLS ARE DEFINED IN THE NOTED FIGURES:

t_{CA} FIGURE C-3

t_{DO} FIGURE C-8

t_R, FIGURE C-8

t_E, FIGURE C-8

t_{DI}, FIGURE C-5

t_{EOB}, FIGURE C-7

t_{ID}, FIGURE C-6

t_{ER}, FIGURE C-6

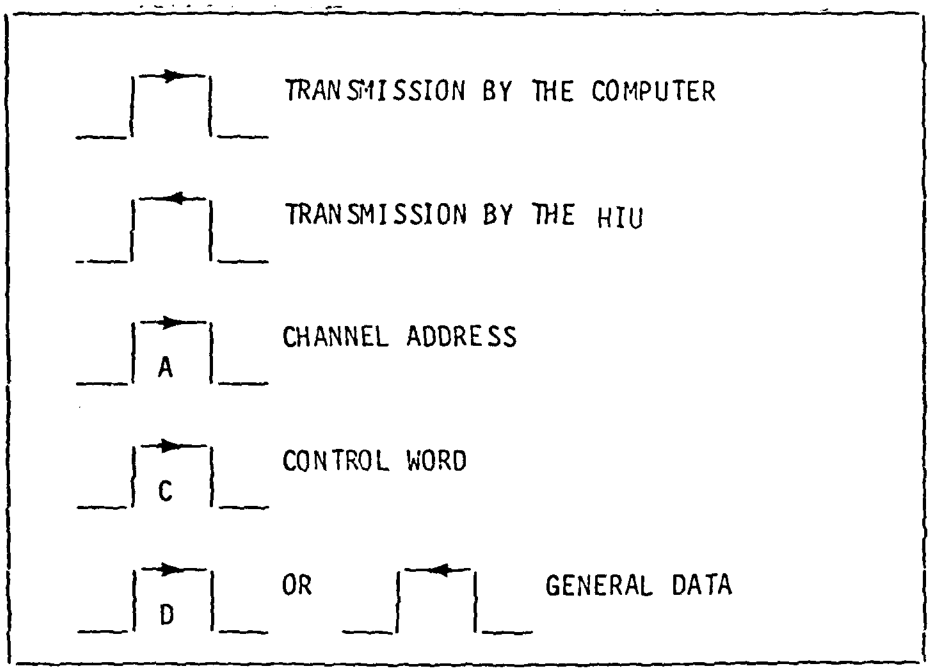
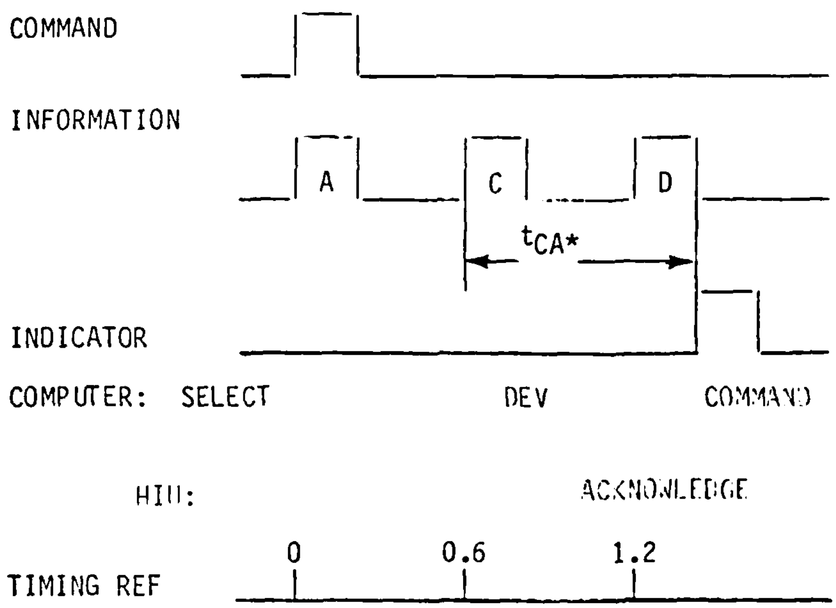


Figure C-2. Timing Diagram Notation

TABLE C-IV. HIU DEVICE COMMANDS

BINARY CODE	ASCII	IF RECEIVE CHANNEL	IF TRANSMIT CHANNEL
0 0 1 0 0 1 0	DC2	BEGIN RECEIVING	COMPUTER INTERFACE LOOP
0 0 1 0 0 1 1	DC3		COMPUTER INTERFACE LOOP
0 0 1 0 1 0 0	DC4	LOCAL LOOP TEST	
0 0 1 1 0 0 0	CAN	STOP RECEIVING	STOP TRANSMITTING PREAMBLE
0 0 1 1 0 1 1	ESC		TRANSMIT, CODED



* ALTHOUGH t_{CA} IS MEASURED FROM THE LEADING EDGE OF THE CONTROL WORD, THE HIU MAY NOT TRANSMIT ACKNOWLEDGE (INDICATOR) UNTIL AFTER THE TRAILING EDGE OF THE COMMAND IS RESPONSE TO DEV

Figure C-3. DEV Operation Timing

7	HIU IS RECEIVING A MESSAGE
6	600 BAUD OPERATION (ALWAYS "0" FOR HIU)
5	SINGLE BLOCK MODE (ALWAYS "I" FOR HIU)
4	CAN'T TRANSMIT
3	A KG IS ON LINE (ALWAYS "0" FOR HIU)
2	Tx BUSY
1	Rx ERROR--RESPONSE TIMEOUT
0	Tx ERROR--RESPONSE TIMEOUT OR PARITY ERROR
P	PARITY (ODD)

Figure C-4. ITR Status Byte

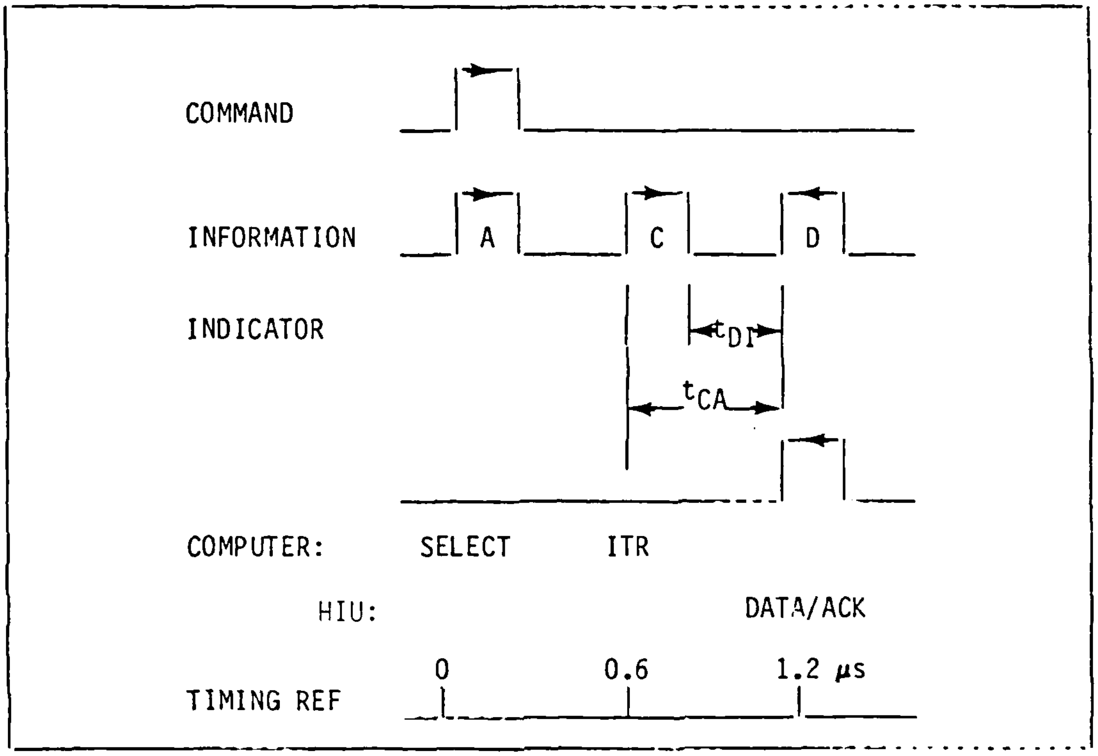


Figure C-5. ITR Timing Sequence

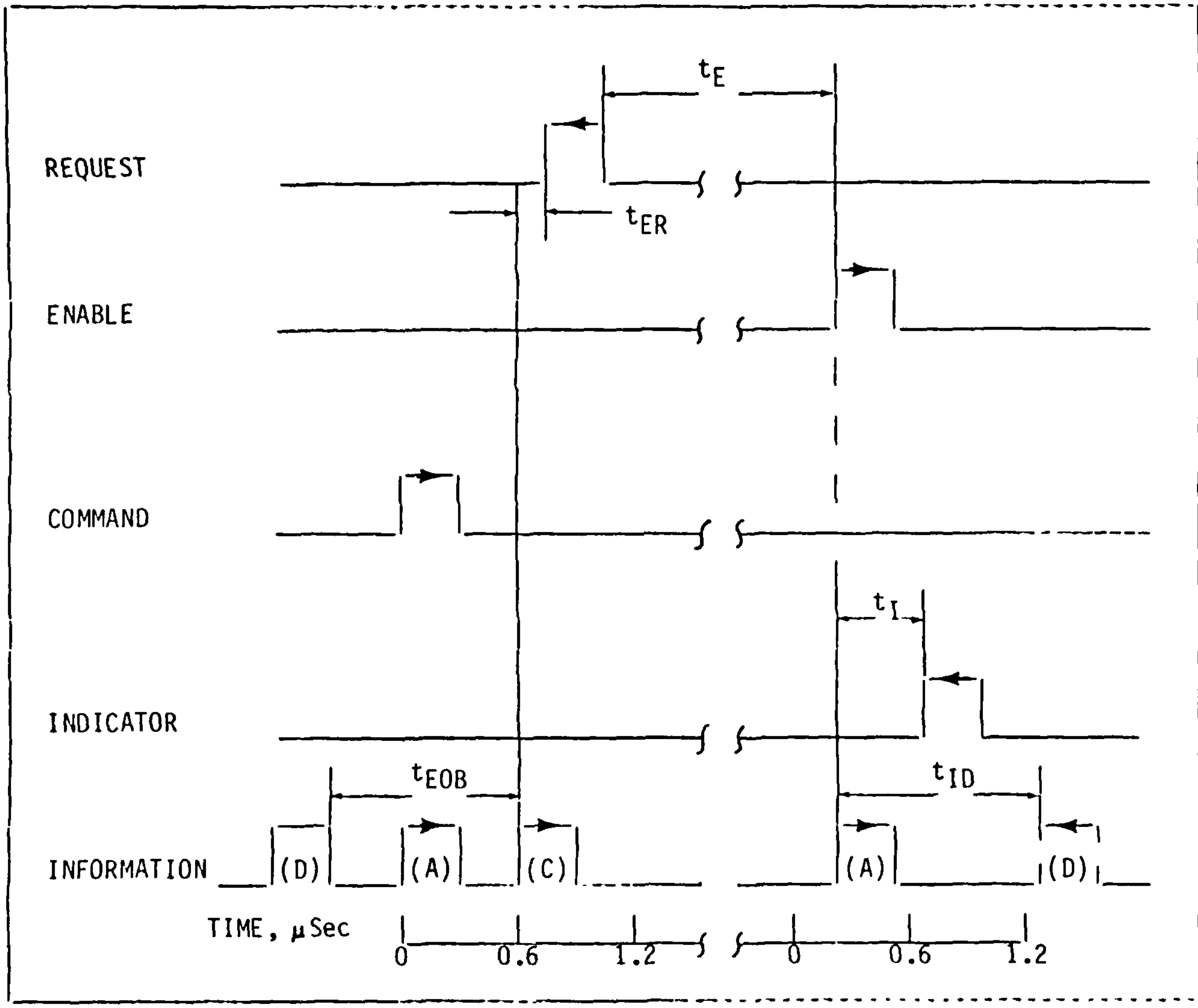


Figure C-6. EOB Sequence Timing

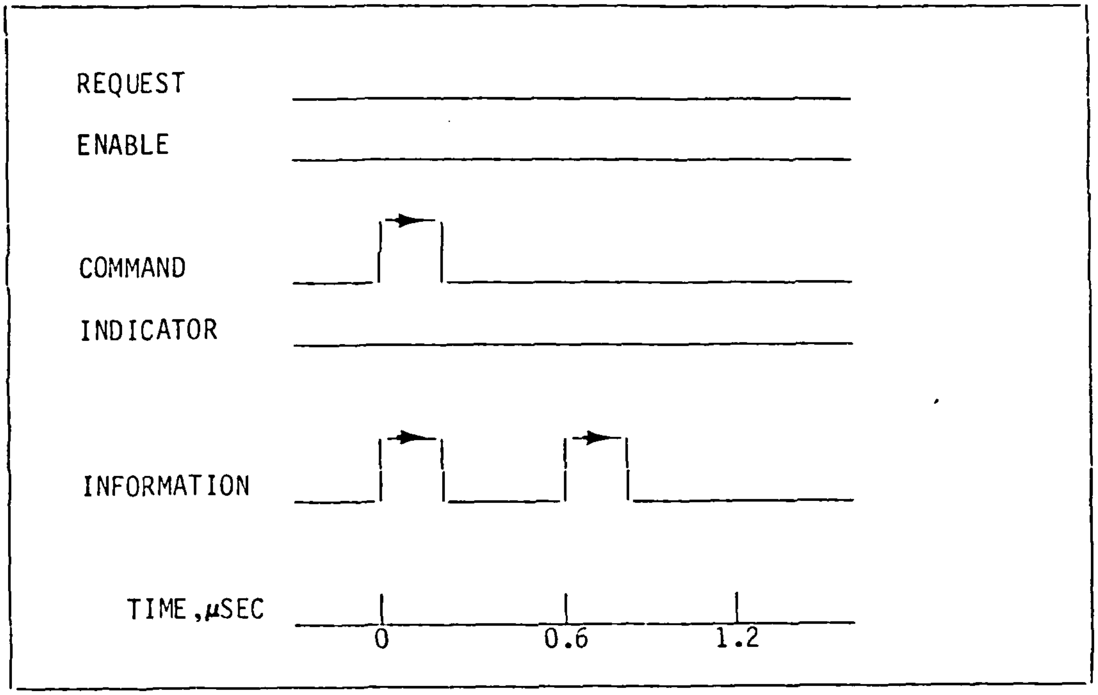


Figure C-7. Stop Sequence Timing

2.2 Computer-to-HIU Data Transfer. The transfer of data characters from the computer to the HIU shall be accomplished as described herein, and as shown in figure C-8. Data transfers rate shall not exceed one character transfer per 250 microseconds.

a. The HIU shall generate a Request pulse for the first character.

b. The HIU, at some later time, shall recognize an Enable pulse from the computer.

c. Data shall be present on the information lines approximately 5 microseconds after the Enable signal.

d. Steps a through c are repeated until an EOB signal is sensed by the HIU, as shown in figure C-6.

2.3 HIU-to-Computer Data Transfer. The transfer of data to the computer shall be accomplished as described herein, and as shown in figure C-9. The transfer of characters shall not exceed one transfer per 250 microseconds.

a. The HIU shall generate a Request pulse for the character.

b. The HIU, at some later time, shall recognize an Enable pulse with the selected address.

c. The HIU shall then place the character on the data lines.

d. Steps a through c are repeated until the HIU has passed the full message to the computer.

e. After the full message is transferred, the HIU shall transfer an EOT to the computer using sequences a through d. The HIU shall then repeat steps a and b and then transmit a pulse to the computer on the indicator line.

f. After e, the HIU shall reset to receive the next message.

2.4 Master Reset. The HIU shall perform a Master Reset when the Enable and Command signals are both present.

2.5 Interface Signal Characteristics. Except for the interlock lines, the HIU shall be connected to the computer using the types of circuits described in the following subsections. Figure C-10 depicts the circuits and communication technique. All lines shall be twisted-pair, signal and return lines. Each signal line shall be terminated by an 82-ohm resistor at the end of the remote line. These lines shall be AC-coupled at the HIU, with a transformer.

2.5.1 Current Convention. The signal currents shall be conventional currents, flowing from positive to negative potentials. A positive current indicates that the circuit is supplying current; a negative current indicates that the circuit is receiving current.

2.5.1.1 Logic Levels. The logic levels for I/O communication shall be as follows:

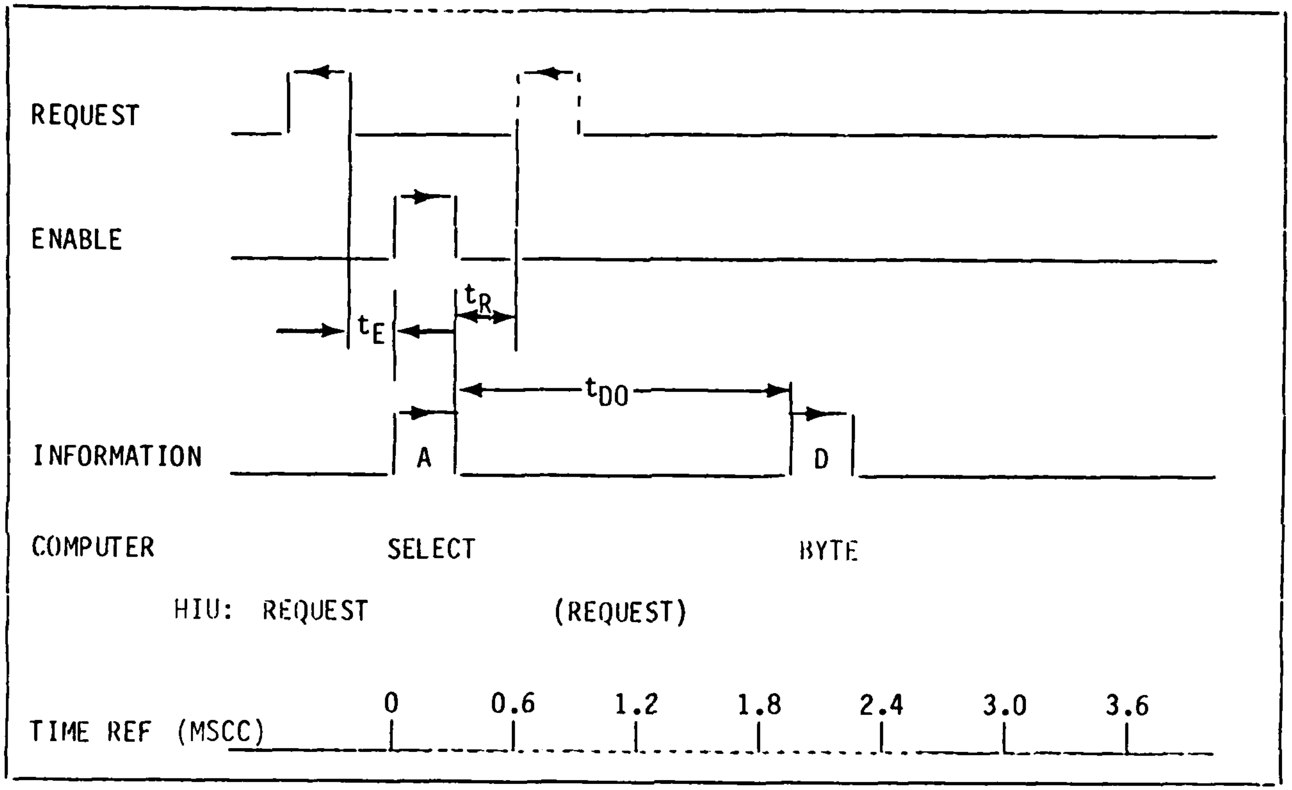


Figure C-8. Computer-To-HIU Data Transfer

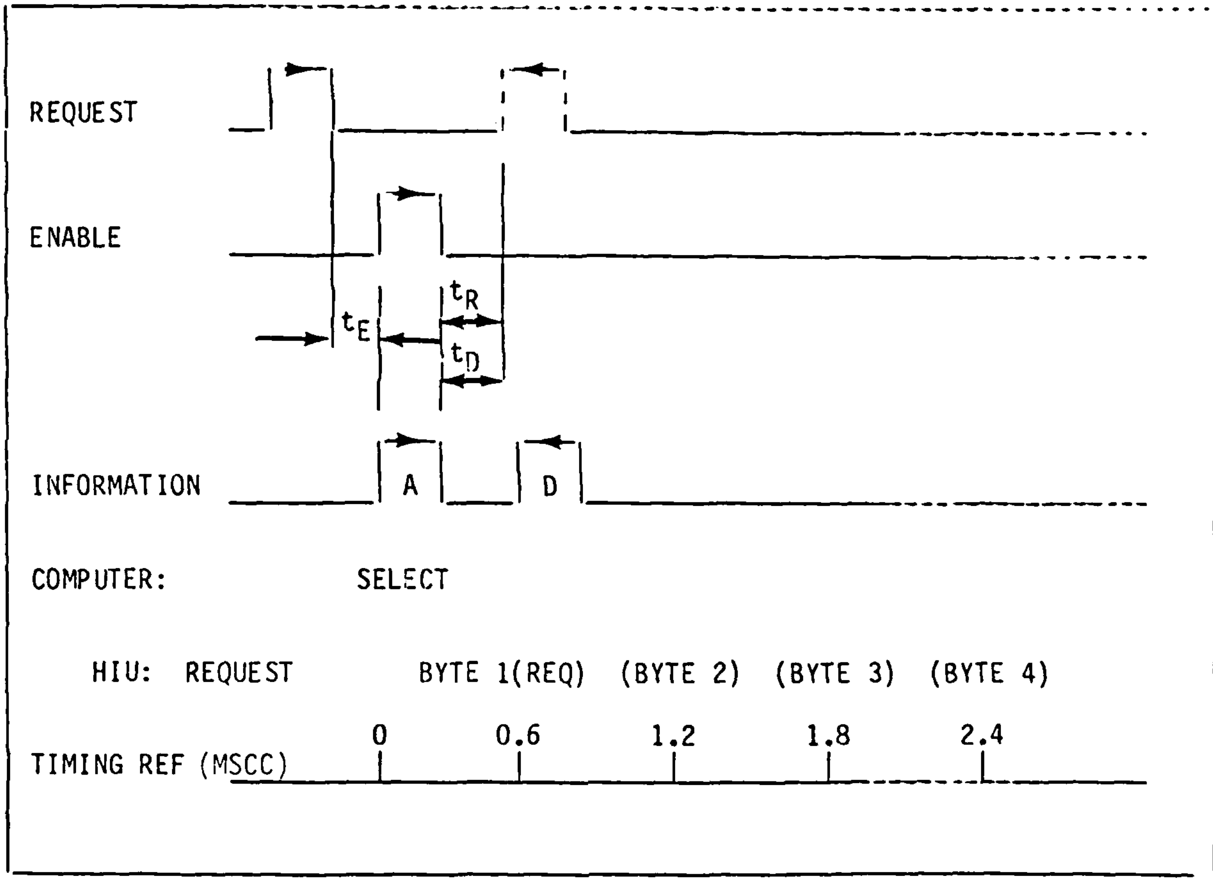


Figure C-9. HIU-To-Computer Data Transfer

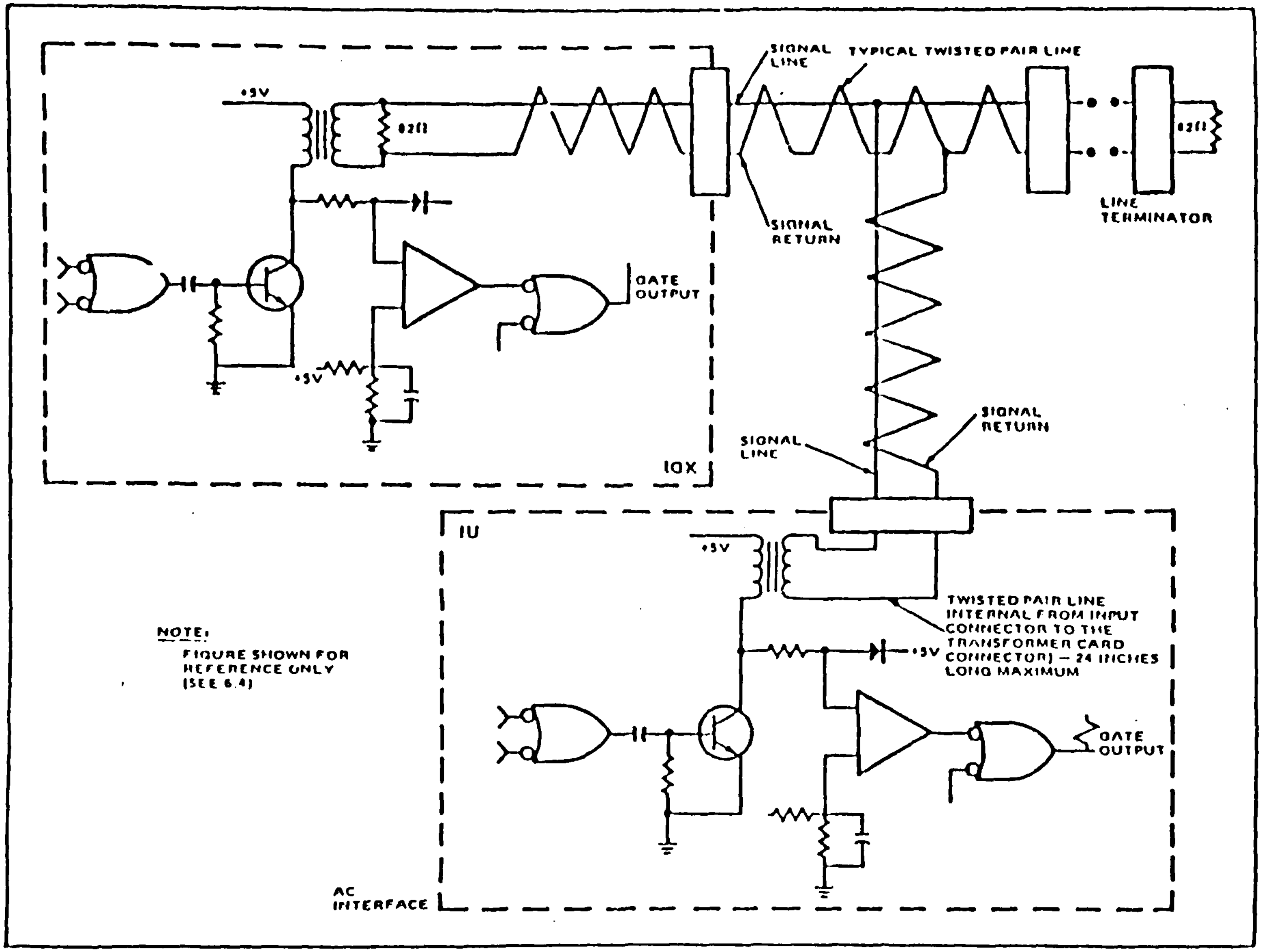


Figure C-10. AC Interface Circuits

a. A logical 1 shall be a pulse with a width greater than 120 nanoseconds and an amplitude greater than 3 volts.

b. A logical 0 shall be a signal not to exceed 0.4 volts on the communication line.

2.5.2 Mechanical Interface. The signal connector used to interface the IU with the computer shall be a 55-pin connector as specified in Litton Specification 586005-635. Pin assignments shall be as shown in table C-V.

TABLE C-V. HIU-TO-COMPUTER (IOX) INTERFACE BUS

SIGNAL	I/O CONNECTOR PIN ASSIGNMENT	SIGNAL	I/O CONNECTOR PIN ASSIGNMENT
INFORMATION BIT P	A	REQUEST 5	f
Return	B	Return	g
INFORMATION BIT 0	C	REQUEST 6	h
Return	D	Return	i
INFORMATION BIT 1	E	REQUEST 7	j
Return	F	Return	k
INFORMATION BIT 2	G	ENABLE	m
Return	H	Return	n
INFORMATION BIT 3	J	COMMAND	p
Return	K	Return	q
INFORMATION BIT 4	L	INDICATOR	r
Return	M	Return	s
INFORMATION BIT 5	N	BURST	t
Return	P	Return	u
INFORMATION BIT 6	R	READY	v
Return	S	Return	w
INFORMATION BIT 7	T	Spare	x
Return	U	Return	y
REQUEST 0	V	Spare	z
Return	W	Return	AA
REQUEST 1	X	Spare	BB
Return	Y	Return	CC
REQUEST 2	Z	COM APP	DD
Return	a	Return	EE
REQUEST 3	b	INTERLOCK (TERMINATOR)	FF
Return	c		
		INTERLOCK (TERMINATOR)	GG
REQUEST 4	d	INTERLOCK (CONNECTOR)	HH
Return	e		

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APPENDIX D

HAMMING CODE GENERATION

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When transmitting a message, five Hamming check bits are generated for each 7-bit character in accordance with table D-I. The X bits shown in the table are set to give the Y bits odd parity. The characters b_1 through b_7 are the data bits, and P_1 through P_5 are the Hamming check bits. An example of the generation of the parity for the ASCII character X is shown in table D-II.

Hamming code bits will be calculated for each 7-bit character in the crypto sync, comm line, text, checksum, and message ending field of a received message, except that the value of the calculated bit (P_5) will be based on the content of the received b_1-b_7 and P_1-P_4) bits. The calculated and received Hamming code bits will be exclusively OR'ed to form a 5-bit correction word (see table D-III). The value of the correction word as specified in table D-III indicates whether the received character code is correct, contains a single (correctable) error, or contains uncorrectable errors.

The content of this appendix is adapted from paragraphs 3.6.1.3.1 - 3.6.1.3.2 of reference 14 (see appendix F).

TABLE D-I. HAMMING CODE GENERATION

P_5	P_4	P_3	P_2	P_1	b_7	b_6	b_5	b_4	b_3	b_2	b_1
				X	Y	Y	Y	Y	Y	Y	Y
			X		Y		Y		Y		Y
		X			Y	Y			Y	Y	
	X				Y	Y	Y	Y			
X	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

NOTE: P_1 IS ODD PARITY ON THE 7 DATA BITS
P_2 IS ODD PARITY ON DATA BITS 1, 3, 5, AND 7
P_3 IS ODD PARITY ON DATA BITS 2, 3, 6, AND 7
P_4 IS ODD PARITY ON DATA BITS 4, 5, 6, AND 7
P_5 IS ODD PARITY ON DATA BITS 1 THROUGH 7 AND PARITY BITS 1 THROUGH 4

TABLE D-II. HAMMING CODE GENERATION EXAMPLE

ASCII CHARACTER	X											
BINARY REPRESENTATION						1	0	1	1	0	0	0
RESULTING CHARACTER WITH PARITY APPLIED	1	0	0	1	0	1	0	1	1	0	0	0
HAMMING BIT IDENTIFICATION	P_5	P_4	P_3	P_2	P_1	b_7	b_6	b_5	b_4	b_3	b_2	b_1

TABLE D-III. PARITY CHECK CORRECTION WORD

CORRECTION WORD P_1 P_2 P_3 P_4 P_5	BIT IN ERROR	DECISION	ACTION
0 0 0 0 0	NONE	CORRECT	ACCEPT CHARACTER, DISCARD PARITY BITS
1 1 0 0 1	b_1	CORRECTABLE	REVERSE STATE OF THE BIT IN ERROR (0 TO 1 OR 1 TO 0 AS REQUIRED), ACCEPT THE RESULTANT CHARACTER, AND DISCARD THE PARITY BITS
1 0 1 0 1	b_2	CORRECTABLE	
1 1 1 0 1	b_3	CORRECTABLE	
1 0 0 1 1	b_4	CORRECTABLE	
1 1 0 1 1	b_5	CORRECTABLE	
1 0 1 1 1	b_6	CORRECTABLE	
1 1 1 1 1	b_7	CORRECTABLE	
1 0 0 0 1	P_1	CORRECTABLE	PARITY BIT IN ERROR; ACCEPT CHARACTER, AND DISCARD PARITY BITS
0 1 0 0 1	P_2	CORRECTABLE	
0 0 1 0 1	P_3	CORRECTABLE	
0 0 0 1 1	P_4	CORRECTABLE	
0 0 0 0 1	P_5	CORRECTABLE	
OTHER VALUES	—	UNCORRECTABLE	DISCARD ASSOCIATED 16-CHARACTER BLOCK (EXCEPT WITH THE RDT)

	b_1	b_2	b_3	b_4	b_5	b_6	b_7	P_1	P_2	P_3	P_4	P_5
RECEIVED CHARACTER AND PARITY	1	0	0	0	1	1	0	1	0	1	1	0
CALCULATED PARITY								0	1	0	1	1
CORRECTION WORD								1	1	1	0	1

CORRECTED BIT - b_3

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APPENDIX E

TACFIRE MESSAGE PROTOCOL

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1. TACFIRE Message Formats. TACFIRE messages are composed of 7-bit ASCII characters. The fixed and variable format messages are shown in figure E-1 and E-2. Format of the message fields is described in the following:

1.1 Message Header. The definition of the header characters is as follows:

a. Character 1 shall indicate the destination of the message. The allowable character set is 0-9 and A-Z.

b. Character 2 is a transmission repeat character. This character can have the values 0-3.

c. Characters 3 and 4 provide a serialization/authentication capability. The allowable character set is 0-9 and A-Z.

d. Character 5 indicates whether the message will be a normal or test message. The character "D" identifies normal data, the character "T" identifies a test message.

e. Character 6 provides device identification. The allowable character set is 0-9 and A-Z.

f. Character 7 defines the message format (delimiter).

1.2 Communications Line Header. The definition of the communications line header fields is as follows:

a. Priority (P). The message priority is determined from the message category and type. If not specified by the FDC operator, the priority is assigned by the computer. The priorities range from one (highest) to seven (lowest).

b. Subscriber (SB). The subscriber is the logical name either of the recipient or the originator of the message and is the logical subscriber name in the SYS;SBT message.

c. Security Classification (C). The security classification field identifies the security level of the message text. The field shall contain one of the following entries:

Character	Meaning
UN	Unc.assified
ETO	Encrypt for transmission only
C	Confidential
S	Secret
C	Confidential formerly restricted data
SRD	Secret restricted data
C*C	Confidential crypto
S#C	Secret crypto

The content of this appendix is derived from appendix IV of reference 19 (see appendix F).

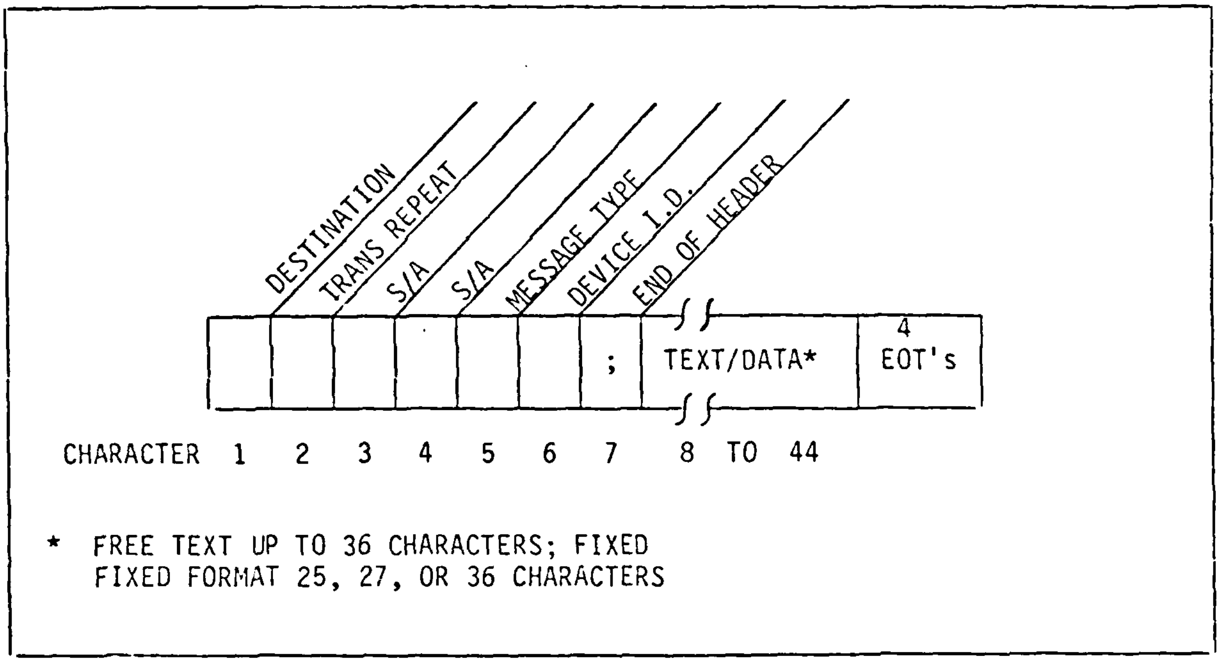

Figure E-1. TACFIRE Message Fixed Format (TF-C)

CHARACTERS	1 7	8 72	73		
	MESSAGE HEADER NOTE 1	COMMUNICATIONS LINE HEADER	TEXT/DATA NOTE 2	CKSUM	CKSUM
FIELDS	1	2 THROUGH 10	11 THROUGH N		EOB

NOTES: 1. MESSAGE HEADER CHARACTERS SAME AS FOR FIXED FORMAT
2. TEXT/DATA FIELDS SHALL CONTAIN A MAXIMUM OF 432 ASCII CHARACTERS

a) VARIABLE MESSAGE FORMAT FIELDS

CHARACTERS	8 11	12 27	28 33	34 42	43 57	58 65	66 69	70	72
	P:_;	SB:_/_/_/_/__;	C:__;	SG:__.__;	DT:__.__/__/__;	ID:____;	A: _;		
FIELD	2	3	4	5	6	7	8	9	10

FIELD

2 PRIORITY (8-11)
3 SUBSCRIBER (12-27)
4 SECURITY CLASSIFICATION (28-33)
5 SEGMENT (34-42)

FIELD

6 DATE-TIME (HR, MIN, SEC) - GROUP DAY (43-57)
7 MESSAGE ID (58-65)
8 AUTOMATIC TRANSMISSION (66-69)
9 IU ADDRESS (70)
10 UNUSED (71-72)

b) COMMUNICATIONS LINE HEADER FIELDS

Figure E-2. TACFIRE Message, Variable Format (TF-A, TF-B)

d. Segment Information (SG). The segment information shall occupy spaces 34 through 42. Spaces 37 and 38 indicate the message segment; spaces 40 and 41, the total number of segments. For example: SG:3-; 10 means that this message segment is the third of 10. If the field is not specified, one segment shall be assumed. A message segment shall be determined by an alphanumeric sequence ending with the end-of-text (EOT) symbol. Error messages linked to a message shall be segment 0 in the comm line (0 of 1), and the message shall be segment 1 of 1.

e. Date Time (DT). The DT occupies spaces 43 through 57 of the comm line. The computer inserts the system date and relay time when the message is received by the FDC and when the FDC operator takes transmit or computer action on a message. On a net monitor error message, the comm line is not modified. Spaces 46 and 47 shall indicate the day, 1 through 31; spaces 49 and 50 specify the hour, 0 through 23; spaces 52 and 53, the minutes 0 through 59; and spaces 55 and 56, the seconds 0 through 59.

f. Messages Identification Number (ID). This is a unique serial identification number assigned by the message processing system. This field occupies spaces 58 through 65, message ID 0000-9999.

g. Automatic Transmission (A). This field occupies spaces 66 through 69. The initial setting of this field shall be blank. If automatic transmission is used, the FDC computer will insert the character A in space 68. The operator directs that an unencrypted classified message (except for crypto classification) be transmitted in the clear by inserting the letter O in space 68.

h. HIU. Space 70 is used to indicate the HIU received the message. The HIU number is supplied by the computer.

1.3 Example Formats. Tables E-I and E-II illustrate two possible message formats in the TACFIRE message set. Note that these are both TF-A variable formats. The first line of each of these two message formats corresponds to the header information illustrated in figure E-2.

TABLE E-I. SYS MISCELLANEOUS INPUT MESSAGE FORMAT

```
______;P:_;SB:_/_/_/__/___;C:UN_;SG:__,__;DT:__,__/__/__;ID:____;A:_;
SYS;MISC;PRINT:0;SPRI:0___;MDSI:0_;LLPI:0_;RLPI:0_;CF:0_____;FS:0_____;
SPR:0;PACK:0;REST:0;DELTAS:0_____;DATE:0_/__/__;TIME:0_/__/__;DELOFF:0;
STAT:0;NETMDE:0/____/_._;DELAY:0_/__/__/__;DIV:0;MPLIST:0;REPORT:0;
PALL:0;PRD:0;PCED:0;PETD:0;PDPM:0;PDDT:0/_/_/_/_/_/_;PELP:0;
PCMU:0/_/_/_/_/_/;PCPU:0;MODE:0___;MFREX:0;CCU:0_ ⌟
```

Purpose: To enter miscellaneous data

TABLE E-II. SYS MDS INPUT MESSAGE FORMAT

```
______;P:_;SB:_/_/_/__/___;C:UN_;SG:__,__;DT:__,__/__/__;ID:____;A:_;
SYS;MDS;MSEL:0_;KGFD:0_/__;BDUFI:0_/__;
LLOOP:0_/__;BDULP:0_/__;ELP1D:0_/__;DDTAD:0_/__;DDTFD:0_/__;ELP1I:0_/__;
RLOOP:0_/__;CPUFD:0_/__;ELP2D:0_/__;DDTBD:0_/__;DDTGD:0_/__;ELP2I:C_/__;
VFMED:0_/__;CMUFD:0_/__;ACCFD:0_/__;DDTCD:0_/__;DDTHD:0_/__;ACCFI:0_/__;
TFDMD:0_/__;ARM1D:0_/__;DPMFD:0_/__;DDTDD:0_/__;ARM1I:0_/__;DPMFI:0_/__;
DIVBN:0_/__;ARM2D:0_/__;ETDFD:0_/__;DDTED:0_/__;ARM2I:C_/__;ETDFI:C_/__⌟
```

Purpose: To initiate or end maintenance and diagnostic (M&D) tests

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APPENDIX F

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APPENDIX G

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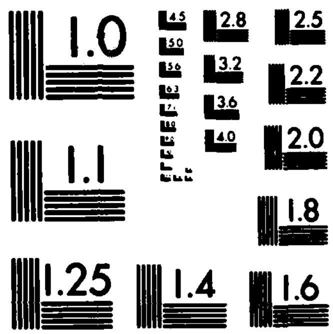

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